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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XV.—*The Magnetic Field in the Jefferson Physical Laboratory*; by R. W. WILLSON, PH.D.

THE Jefferson Physical Laboratory of Harvard University consists of two wings each 60 ft. square, connected by a central portion 80 ft. in length. The western wing is allotted exclusively to original work and special research, and is constructed wholly without iron. It is of course impracticable entirely to exclude magnetic material from the rooms of a building devoted to these objects, but the absence of all iron from the materials of the building itself, making it certain that no disturbing cause lies hidden from view in the walls, that the gas and steam pipes are of harmless material, and that a sensitive instrument may be even set upon the floor without possible risk of disturbance from the nails, is an advantage which will be appreciated by those who are familiar with magnetic measurements.

As the entire avoidance of iron adds largely to the cost of construction of a building 60 ft. square, with three full stories above a high basement, heated by steam pipes in each room and well piped for gas, it is desirable to know how far the end sought has been attained, and as the experiment has rarely, perhaps never, been tried elsewhere upon so extensive a scale, the incomplete series of observations of which I here give the results have a general interest. That a complete survey of the whole wing was out of the question is evident, for while these observations were in progress much other work was being done, some of which required the use of dynamo currents, while in one of the rooms a considerable magnetic disturbance arose from the presence on the floor above, of an iron stove in constant

use for other investigations. With one exception this stove was the only mass of iron casually present whose effect it was not easy to eliminate by reversal or removal at the time of the observations.

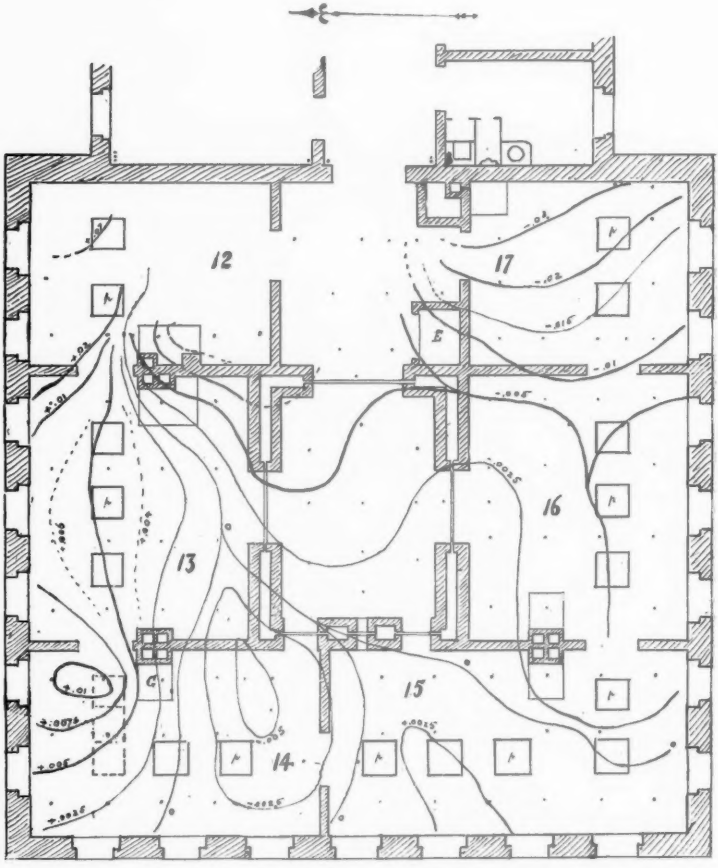

Fig. 1. Plan of west wing of the Jefferson Physical Laboratory, with lines of equal directive force in planes 5 ft. above first floor.
E, elevator.
G, point below iron stove on second floor.
p p p, piers.

When by the courtesy of Prof. Trowbridge and the Director of the Laboratory, Prof. Lovering, I obtained for a special research the use of one of the rooms of the non-magnetic wing (No. 17 on the plan fig. 1), it became necessary for me to in-

vestigate the variations of the magnetic field in different parts of the room. For this purpose I made use of the very convenient local variometer devised by Prof. F. Kohlrausch.*

A very few observations showed that the Horizontal Intensity H, acting upon a free magnet was quite variable as will be seen by reference to fig. 1 which shows a system of lines upon each of which the directive force is the same. The general form of the disturbance of the earth's uniform field pointed to a source of free north magnetism in the neighborhood of the N. E. corner of the room, and the stack of iron soil pipe shown at S, fig. 2 was examined and found to be inadequate to produce so great an effect as was observed. This is not surprising since, though of large size, it is made up of short lengths with leaded joints and acts as a series of separate magnets end to end. The neighboring iron steam pipes at C showed a far greater amount of free magnetism, enough indeed to account for the greater part of the disturbance noted.

Feeling desirous to know more of the extent of this effect I made a series of observations on each of the piers *p*, *p*, on the first floor establishing the fact that in the rooms 13, 14, 15 and 16 the greatest deviation of the Horizontal Intensity from its mean value was one half of one per cent. The differences were so large, however, that I determined to make a more extended set of observations, including about twenty-five points on the third floor and several in the basement. The result showed that besides the effect of the stove temporarily used in the room on the second floor over room No. 14, a considerable disturbance was perceptible even in those rooms farthest removed from all iron.

Further observations on the third floor were discontinued on account of the establishment there before the series was complete of the long iron beam which was at this time put in place for the work of Prof. Trowbridge on the spectra of metals.† The frequent changes of position of this beam gave rise to a variable disturbance which was of some magnitude on the third floor though fortunately very small below.

I then determined to make a careful survey of the first floor, the only part of the building in fact where measures are likely to be made which require great uniformity of field over large spaces. The results of this campaign are given in fig. 1; observations were made at the points indicated by dots, the plane of the instrument being five feet above the floor and two feet and three inches above the tops of the piers, this being assumed a sufficient distance to prevent any disturbance from the brickwork of the piers. The lines connect points at which the directive force is the same; at points on adjacent lines the force differs by one quarter of one per cent. of its whole amount,

* Wied. Ann., xix, p. 130, 1883. † Proc. Am. Acad., 1888, p. 1.

the positive sign indicating excess over the normal value which is assumed to be that at the southwest corner of the building, being nearly the mean value for rooms 13–16 and differing by one fifth of one per cent from that in the tower sixty feet from the ground. The season of the year made it impracticable to make a satisfactory comparison with points out of doors.

It is obvious that, as was inferred from the first observations on the piers in rooms 13–16, over much more than nine tenths of these four rooms the greatest variation from the value assumed as normal did not exceed one half of one per cent. In room 12, however, the variations were so great that a complete survey was not attempted; the difference between the two piers for instance being four per cent. The disturbance in room 14 is such as would be produced by the iron stove on the second floor above the point G, if magnetized in the direction of the dip, about 60°. The symmetry of the disturbance in rooms 12 and 17 led to a closer examination of the steam pipes against the east side of the eastern wall forming the boundary of the non-magnetic wing of the building. Of these there are three groups. At A, B and C, fig. 2 are pairs of pipes reaching from the basement to the second floor, and at A is a third pipe reaching from the basement to the third floor.

The strength of the free north magnetism at a point five feet above the first floor was found to be such as to give at a distance of 10 feet a field of .025 H for C and .04 H each for A and B. To compute the effect of these pipes upon the directive force over the whole ground to be covered, seemed at first sight an undertaking of considerable magnitude, involving the determination of the distribution of magnetism not only throughout their whole extent, but also in that of the whole system of iron steam pipes in the basement and of a large radiator connected with A upon the third floor, and consisting of five parallel horizontal pipes each fifty feet in length. As a matter of curiosity, however, the following investigation was made.

Upon the platform of the elevator at E was placed a simple magnetometer read with mirror and scale, the readings of which as the elevator car was raised or lowered served directly to determine the difference of the magnetic declination at different points in the vertical line above E. These differences referred to a point 10 ft. above the first floor were as follows:

4 ft.	above	basement	floor,	3°·32 W.
9 "	"	"	"	3·00 W.
4 "	"	first	"	1·75 W.
10 "	"	"	"	0·00
4 "	"	second	"	1·18 E.
10 "	"	"	"	1·21 E.
4 "	"	third	"	1·81 E.

The distance between the floors is 12 feet, from the basement to the first floor 10 feet.

As it appeared therefore that the distribution of the free magnetism in the pipes,—if the sole cause of the differences of declination observed,—was such that its variation was not far from symmetrical above and below the plane of observation of

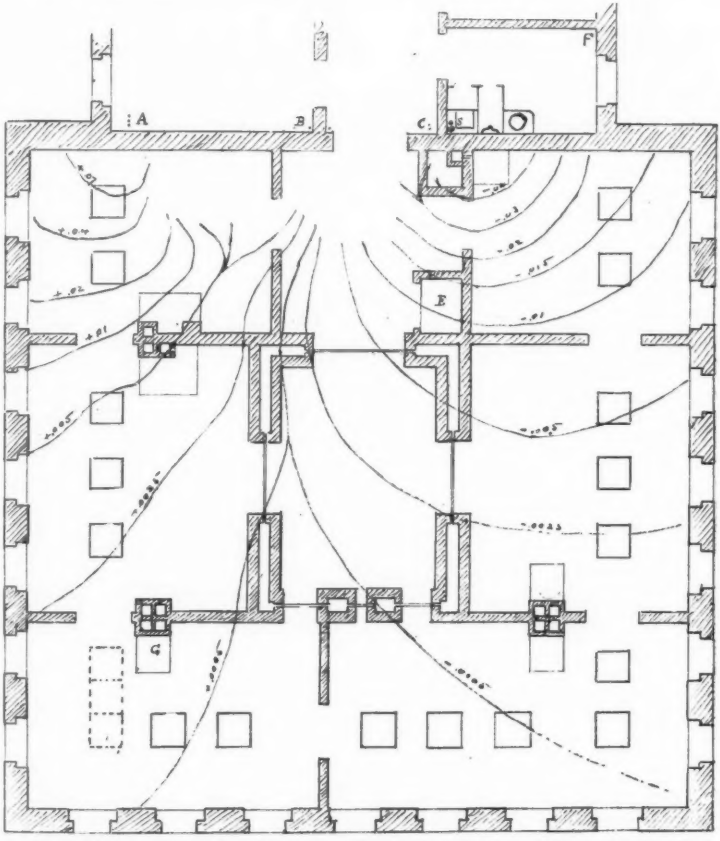

Fig. 2. Plan of west wing of Jefferson Physical Laboratory with lines showing disturbance of the earth's directive force, produced by steam pipes at A, B, C and F.

the Horizontal Intensity, I determined as a first approximation to compute the alteration which would be produced in the uniform field H throughout that plane by the free magnetism indicated by the direct observations upon the pipes, i. e. of three north poles five feet above A, B and C and of the strengths above determined.

Fig. 2 gives the results of this computation, the lines connecting points at which the effect of the pipes as computed on the above assumption is to increase the Horizontal Intensity by equal amounts. From this plotting the value of the disturbance at each of the various points of observation due to the

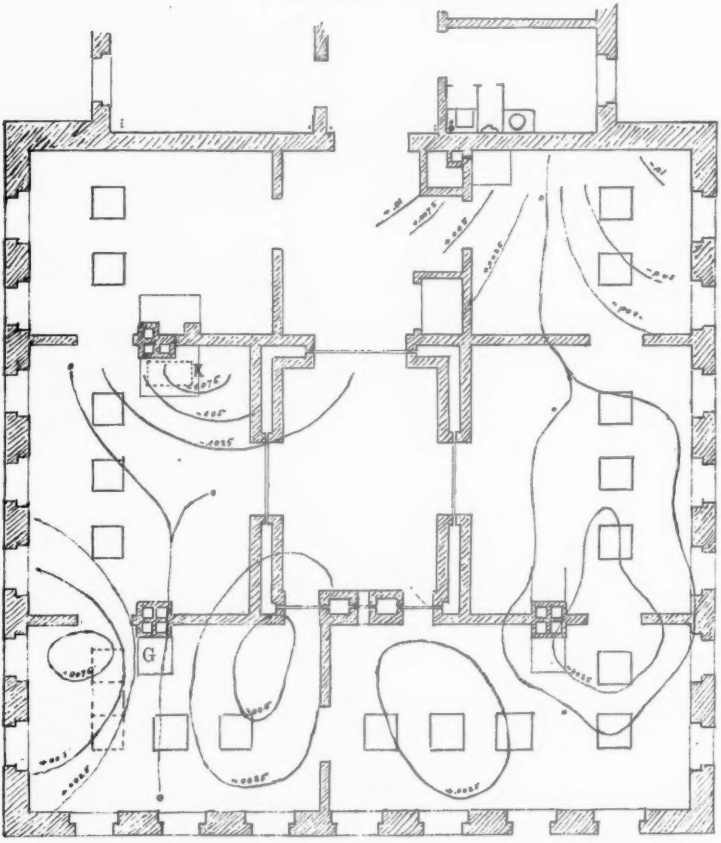

Fig. 3. Plan of west wing of Jefferson Physical Laboratory with lines showing disturbances of the earth's directive force, due to causes other than presence of steam pipes shown on Fig. 2.
G, point below iron stove on second floor.
K, point below iron base plate on second floor.

presence of the pipes was determined and subtracted from the corresponding observed values as shown on fig. 1. By the use of the numbers thus obtained a new system of lines of equal directive force was found which probably fairly represents the

field as it would be but for the presence of the pipes; these lines are shown in fig. 3.

Here are clearly shown four distinct disturbances:—(1) That in the S. E. corner of the wing which was at once attributed to a pair of steam pipes at F, nine feet from the eastern wall of the wing and reaching from the basement to the third floor, which had been overlooked until pointed out by this system of lines. (2) That in the N. W. corner due to the stove above G as before described. (3) That in room 13, which might be produced by a horizontal magnet above or below the point K with its north pole directed toward the north. Search showed the probable cause in the presence on the second floor of a heavy iron table top four feet long, two feet wide and an inch thick, whose position is indicated in fig. 3. (4) A disturbance in rooms 15 and 16 which has not been traced to its source.

The foregoing account contains the substance of a paper read before the Mathematical Physical Club of Boston and Cambridge, May, 1887. I had hoped to extend the observations and especially to investigate the last mentioned disturbance in rooms 15 and 16. It is only within the last month, however, that I have again taken up the subject and have been able to show that the brick piers have a sufficient amount of free magnetism to produce the observed effect. These results I shall make the subject of a future paper; meanwhile the present writing will serve to show the magnitude of the disturbance which may arise in practice from such common objects as stoves and iron pipes.

Jefferson Physical Laboratory, Nov. 1889.

Art. XVI.—*On Cretaceous Plants from Martha's Vineyard;* by David White.*—With Plate II.

It is remarkable that, although the existence of fossil vegetable remains on Martha's Vineyard has been on scientific record for nearly one hundred years, and the announcement, accompanied by several figures, of the occurrence of dicotyledonous leaves at Gay Head was made in the report of the State Geologist of Massachusetts over sixty years ago, no one has ever made a systematic study of the entombed plants, nor attempted to draw any evidence therefrom as to the age of the containing strata. No one seems ever to have searched there for plants with that object in view. The probable reason for this is the lack of importance which they had in the eyes of the State geologist, as well as the crude and indeterminate

* Published with the permission of the Director of the U. S. Geological Survey.

illustrations of the six specimens that were figured. Certainly nothing has been added meanwhile to the knowledge of the matter gained a half century ago, and which may be summarized in the fact that fossil dicotyledonous plants existed at Gay Head.

As a result of a visit paid to Martha's Vineyard last summer, in company with Professor Lester F. Ward of the U. S. Geological Survey, by whose courtesy the material was referred to me for examination, I was so fortunate as to find a large number of specimens of plants, which, though generally rather poorly preserved, will perhaps furnish important aid in solving the vexed question as to the age of the underlying clays, lignites and sands of Martha's Vineyard. In order, however, that the facts about to be brought forward may take their true position and color in the perspective of evidence and previous opinions as to geological age, it will be well to make a brief review of preëxisting data and opinions.

As early as October, 1786, Samuel West, in "A Letter Concerning Gay Head,"* described the striking color effect and the disturbance of the strata, and noted the occurrence of fossil wood and bones; and Dr. William Baylies, who aided him, and whose letter follows† the other, agreed with Mr. West in regarding the upheaval of the cliffs as due to volcanic action. He found what he considered to be five or six craters, and observed the presence of whales' bones, sharks' teeth and petrified shell-fish. The island is not colored on Maclure's map, nor mentioned in his explanation.‡ In 1824, John Finch§ expressed the belief that the Gay Head clays, in common with the clays at Sand's Point on Long Island, Amboy in New Jersey, and those of Cape Sable, Florida, Alabama and Mississippi, were of the same age as the Alum Bay clays in the Isle of Wight. The same year, Edward Hitchcock, in some "Notices of the geology of Martha's Vineyard and the Elizabeth Islands,"‖ seemed inclined to consider the clays of Gay Head and the Chilmark Cliffs (he visited the latter only) as equivalent to the European Plastic Clay formation, and they were so colored on the accompanying map. The same volume¶ contains a review of Conybeare and Phillips' "Outlines of the Geology of England and Wales," in which the reviewer asserts the identity of the Plastic clays of Europe with those of Gay Head.

* Samuel West: dated Oct. 9, 1786, Mem. Am. Acad. Arts, Sci., vol. ii, 1793, p. 147–150.

† l. c., pp. 150–155.

‡ William Maclure: Observations on the geology of the United States, explanatory of a Geological Map, Trans. Am. Phil. Soc., vol. vi, pt. 2, 1809, pp. 411–428.

§ John Finch: Geological Essay on the Tertiary Formations in America, this Journal, vol. vii, 1825, pp. 31–43.

‖ l. c., pp. 240–248, pl. iv.

¶ l. c., pp. 203–240.

The report of the State geologist, published in 1832,* contains a map on which this region is colored and described as Tertiary. In the Report published in 1833,† which was accompanied by a map and atlas, the organic remains are discussed and figured, and a short description of the Gay Head cliffs is given. The same material, so far as it concerns Martha's Vineyard, is repeated in the "Final Report," of 1841,‡ with a more extended stratigraphical description, and a section of the cliffs. This is the most important contribution to the subject that appeared prior to Professor Shaler's work in 1889. From the similarity of the lithologic characters, and the evidence of the organic remains, the conclusion is reiterated and confirmed that the clays are Eocene, and equivalent to those of Europe. Dr. Hitchcock regarded many of the fossils, especially the bones, as having been rolled and broken, probably from re-deposition. A description of the strata, mammals, fishes, crustacea and mollusca was given in 1844 by Lyell,§ who saw no indications of the occurrence of Cretaceous strata in any fossils appearing to have been washed out from the Cretaceous to form the clays, which were judged by him to be Miocene. Save Professor H. D. Rogers' assent‖ to Sir Charles' conclusions, and Desor and Cabot's correlation of the clay at the base of Sankoty Head in Nantucket with those of Gay Head, which they regarded as representing the opposite side of a Miocene basin,¶ there seems to have been no further discussion of the subject till 1860, when Dr. William Stimpson announced the discovery, without giving descriptions, of new fossils, bones, mollusca, etc., which persuaded him that the strata were Cretaceous, rather than Eocene.** Three years later†† he added a description of *Archæoplax signifera*, a new genus and species of fossil crab, which,

* Edward Hitchcock: Report on the Geology of Massachusetts; examined . . . during . . 1830 and 1831, this Journal, vol. xxii, 1832, pp. 1–70. The same was published that year as the regular Report of the Survey, "pt. 1, Economic," and comprises pt. 1 of the Report for 1833.

† Report on the Geology, Mineralogy, Botany and Zoölogy of Massachusetts, etc., 1833, with map and atlas. (See pp. 172–204, pl. xi.)

‡ Final Report on the Geology of Massachusetts, vol. ii, 1841. (See pp. 422–434, pl. xix, liv.) The clays are mentioned in nearly every report which touches upon the economic geology of the State; only those in which their age is considered are here included.

§ Sir Charles Lyell: On the Tertiary Strata of the Island of Martha's Vineyard in Massachusetts, Proc. Geol. Soc. London, vol. iv, No. 92; this Journal, vol. xlvi, 1844, pp. 318–320.

‖ H. D. Rogers: Address before the American Assoc. Geol. and Nat., May, 1844, l. c. vol. xlvii, 1844, pp. 247–278.

¶ E. Desor and E. C. Cabot: On the Tertiary and more recent Deposits in the Island of Nantucket, Quart. Jour. Geol. Soc., London, vol. v, 1849, pp. 340–344, 2 figs.

** William Stimpson: Cretaceous Strata at Gay Head, this Journal, II, vol. xxix, 1860, p. 145.

†† On the Fossil Crab of Gay Head, Boston Jour. Nat. Hist., vol. vii, 1863, pp. 583–589, pl. xii.

from its distant relation to other fossil crabs, afforded but little aid in determining the geologic age of the terrane. However, for some reason not given he withdraws his statement as to their Cretaceous age. Dana, in his "Manual of Geology,"* adopts the view generally accepted that the beds were of the Yorktown (Miocene) Period.

Except the map prepared for the Centennial Commission,† in which the western end of the island is colored Miocene, and a notice of the opinion expressed before the New York Academy of Sciences by Professor Merrill,‡ in which he referred the Gay Head strata to the Post-Pliocene or Quaternary, nothing further seems to have appeared until the publication (1889) of Professor N. S. Shaler's excellent "Report on the Geology of Martha's Vineyard,"§ in which the stratigraphy of Gay Head is treated at length with full illustrations (p. 328–332, pl. xxvi–xxviii). There the series exposed at Gay Head received the name of "Vineyard Series." His conclusion (pp. 332, 333) is that this series "must be considered as belonging to one great division of the Tertiary deposits;" and when speaking of its outcrop at Indian Hill he says: "This part of the Tertiary series is certainly of later Miocene or Pliocene age." Professor Shaler makes no enumeration or discussion of the fossils, all paleontological data being left to a future report. More recently, in a short paper on some Cretaceous fossils,‖ which were obtained at several points in the drift on the more eastern portion of the island, and which seem to indicate a lower Cretaceous age, he points out the distinctions between their probable source and the Vineyard Series, reiterating his conclusion as to the Miocene or early Pliocene age of the latter, and adding that "a careful study of all the exposures on Martha's Vineyard containing Tertiary clays has failed to show any distinct fragment of Cretaceous rock."

It is obvious from the foregoing review that the prevailing opinion favors a Tertiary, probably Miocene, age for the "Vineyard Series," and the re-deposition of the Cretaceous invertebrates in the younger formation.

The material collected last summer was found at several localities and horizons in the Vineyard Series. The former include the Kaolin clays at Peaked Hill in the western part of the town of Chilmark, the carbonaceous clays at Nashaquitsa

* J. D. Dana: Manual of Geology, ed. 1864, pp. 510, 511; ed. 1875, pp. 494, 495; ed. 1880, p. 495.

† W. O. Crosby: Report on the Geological Map of Massachusetts, Boston, 1876.

‡ F. J. H. Merrill: Geological Structure and Age of the deposits at Gay Head, Mass., Trans. N. Y. Acad. Sci., vol. iv, 1885, p. 79.

§ Seventh Ann. Rept. U. S. Geol. Survey, pp. 297–363, pl. xix–xxix.

‖ On the occurrence of fossils of the Cretaceous Age on the Island of Martha's Vineyard, Mass., Bull. Mus. Comp. Zoöl. Harvard Coll., vol. xvi, No. 5, 1889, pp. 89–97, pl. i, ii.

Cliffs on the south shore of the same town, and various points in the promontory of Gay Head. Fossil wood, more or less lignitized, is found wherever the series is met with. This promontory, about one hundred and forty feet in height, and five eighths of a mile in length, is the typical section of the Vineyard Series. Here remains of dicotyledons were found in the lignitic clays and sands of the south face, the gray and reddish clays and the limonite and the lignites on the west, and the carbonaceous clays on the northwest face of the cliffs.

The greater part and the best of the specimens were obtained (1) from argillaceous concretions in the lignites and carbonaceous clays, (2) from the clay and clay-ironstone concretions in the reddish and gray clays, and (3) rarely from the concretions and the limonite matrix of the ferruginous conglomerates on the western escarpment. Some fine specimens were procured from concretions in an arenaceous lignitic clay at Nashaquitsa. Those plants found in the soft clay matrix on the northwest and south shores of Gay Head, at Peaked Hill, and at Nashaquitsa, though in rare instances determinable, soon became worthless upon exposure to the air.

The plant collection embraces Cryptogams, Conifers, Monocotyledons and Dicotyledons. Numerous fruits were obtained. The aspect of the flora, as a whole, seems pre-Tertiary. Many of the dicotyledons appear to represent archaic types, and the greater part are unlike any that have yet been described.

It is my purpose in this preliminary paper to select from those specimens thus far identified a few which are the most characteristic, and which have probably been described from other localities or formations. They are as follows:

Sphenopteris grevillioides Hr.
Sequoia ambigua Hr.
Andromeda Parlatorii Hr.
Myrsine borealis Hr.
Liriodendron simplex Newb. (*L. Meekii* Hr., in part.)
Eucalyptus Geinitzi Hr.
Sapindus cf. *Morrisoni* Lx.

Of these species, *Sphenopteris grevillioides* Hr. was found in the Kome beds (Lower Cretaceous) of Greenland. The specimen figured, Pl. II, fig. 1, agrees well with Heer's description, while other fragments in the collection, probably from lower pinnæ, show the entire margins figured by Heer.

Sequoia ambigua Hr., Pl. II, fig. 2, 3, has been found in the Kome beds, and in the lower Atane beds (Middle Cretaceous) of Greenland.

Andromeda Parlatorii Hr., Pl. II, fig. 4, has been reported from the Dakota group (Middle Cretaceous) of Kansas and Nebraska; from the Lower Atane beds of Greenland; and from strata of unsettled age, but probably Cretaceous, from Las Animas, Colorado, and the Bozeman mines of Montana. Though the specimen figured is only the lower half of the leaf,

it corresponds precisely with Heer's original description, including the transverse striations of the midrib, while the areolation is like that given by Lesquereux in his Cretaceous Flora, pl. xxiii, fig. 6.

Myrsine borealis Hr., Pl. II, fig. 5, was described by Heer from the Liriodendron bed (Lower Atane) of Greenland.

Liriodendron simplex, Pl. II, fig. 7, was described by Newberry (Bull. Torrey Bot. Club, vol. xiv, 1887, p. 6, pl. lxii, fig. 2–4) from the Amboy clays (Middle Cretaceous) of New Jersey and Long Island. Dr. Newberry considers the forms from Greenland identified by Heer as *L. Meekii*, *Leguminosites Marcouanus* and *Phyllites obcordatus*, as the Amboy species. But whether the Greenland forms of *L. Meekii* are identical with *L. simplex*, or whether the latter is a Liriodendron at all, are questions which cannot be discussed here, nor do they greatly affect the geological relations of our flora. The Amboy clay *L. simplex* is identical with the form which is by far most abundant in the Gay Head flora. The leaf represented in fig. 6 agrees with the Greenland *L. Meekii* Hr., which is so abundant and characteristic of a horizon in the Lower Atane strata that that part is commonly known as the "Liriodendron bed." Fig. 6 coincides most nearly with Heer's specimen from the Patoot beds (Upper Cretaceous) of Greenland. It is somewhat doubtful whether Heer's original specimens or his synonyms from the Dakota group of Nebraska are the same species as his Greenland specimens. It is notable that Lesquereux regarded *L. Meekii*, *Leguminosites Marcouanus* and *Phyllites obcordatus* from Greenland as belonging to *L. primævum* of Newberry, from the Dakota group. Either relation is quite possible, especially in view of the known variation in the leaves of a single species, or even tree, of Liriodendron.

Next to the preceding species, the most numerous of the plants from Gay Head is *Eucalyptus Geinitzi* Hr., fig. 8–11, two of whose fruits, "resembling unopened flowers of syngenesian plants," were figured as "scales of vegetable remains" in Hitchcock's Final Report. This species, first described from the Liriodendron beds (Middle Cretaceous) of Greenland, is abundant in and most characteristic of the Middle Cretaceous of Bohemia, and is also present in the same stage (Cenomanian) in Moravia. The specimen, fig. 11, is included here on account of its coincidence with one figured by Velenovsky (Foss. Fl. böhm. Kreide., iv, pl. xxv, fig. 7), which he supposed represented a flower of this species. It may belong to a conifer.

The remains of the nuts show longitudinal furrows (white in the figures) filled with a resin which is "indistinguishable by ordinary tests from Amber," and which was observed and pronounced amber by Hitchcock in 1841. These doubtless are

the remains of gum or oil vessels, such as exist in the nuts of recent Eucalypts; and the granules of "amber" can hardly be else than Eucalyptus gum.

The explanation is at once suggested that the fragments of amber observed by various writers, during the last hundred years, about Gay Head, and in the New Jersey Cretaceous, where also Eucalypts are found, are the product of the contemporaneous "gum-trees," rather than of some conifer. None of this American amber has, I believe, been tested for succinic acid, or to show its relation to true amber.

Although the tertiary nervation of the figured specimen of *Sapindus*, fig. 12, is wanting, I have little doubt, after comparing it with the figures by Lesquereux and Heer, that it is referable to *S. Morrisoni* Lx., from the Dakota group of Nebraska, Lower Atane beds (Middle Cretaceous), and from the Patoot beds (Upper Cretaceous) of Greenland.

As was remarked above, a large part of the Gay Head species seems to be as yet undescribed. Of the remainder, all the identified species are found in the Cretaceous, and all but *Sphenopteris grevillioides* Hr. were present in the Middle Cretaceous. The relation of the Gay Head flora with that of the Middle Cretaceous (Cenomanian) of Greenland seems nearer than that with the flora of the Dakota group. There is, however, every reason for believing that it will be found to be very largely identical with the flora of the Amboy clays, from which, unfortunately, only six species have as yet been published. It is hoped that Dr Newberry's forthcoming monograph of that rich flora will soon appear.

The evidence, then, of the fossil plants bespeaks an age that is decidedly Cretaceous, and probably Middle Cretaceous, for the terrane in which they were deposited.

The question which was raised in the case of the Cretaceous invertebrates will doubtless be repeated as to the plants, viz: whether the immediate matrix in which the plants are found is not either transported and re-imbedded rock, rather than of the nature of true concretions; or whether, supposing the concretions to be genuine, they may not have existed as such in the older formations whence that part of the Gay Head sediment was derived. The circumstances which unite to prove that the plants lie in their original matrix and terrane are as follows: The plant-bearing concretions, which are generally more or less lenticular or oblong-lenticular, sometimes geodic or columnar within, show, often clearly, the concentricity of their structure. In many cases they are formed about a stem-fragment of quite large size. Some are concreted about balls of clay or sand. The leaves, which are often thickly matted, may occur in any zone, and are usually parallel to the longer axes of the concre-

tions. Those found in the thicker lignites seldo anything determinable, a large portion of the material consisting of woody debris more or less pyritized. They do not show such erosion or abrasion as would be expected had they been transported. Pyritic nodules are still forming in many of the strata. Both at Gay Head and at Nashaquitsa, in the carbonaceous clays, nodules were observed by Professor Ward, who made a review of the ground with me, and myself apparently in process of formation, the margins and outer layers presenting all the stages of transition from the center of the concretion to the general matrix of somewhat sandy carbonaceous clay, which composed the strata. The planes of the nodules are parallel to those of the stratification. We also observed, especially at the latter locality, some cases in which the leaves lay partly within the hard part of the concretion, extending through the intermediate transition material. The plants found in the clays themselves were most difficult to handle and extremely perishable so that none could be preserved; but such comparisons of those that were determinable as could be made on the spot pointed to the identity of the species. Many of the nuts of the Eucalyptus and other fruits, with fragments of stems of various plants were found in the limonitic matrix of the ferruginous conglomerate. This matrix can hardly be regarded as transported.

Similar plant-bearing nodules have been reported by Professor N. L. Britton from the Amboy Clays on Staten Island, and along the Raritan River in New Jersey.* The extension of these New Jersey Cretaceous Clays to the eastward, first pointed out by Mather, is now generally accepted,† Glen Cove on the northern shore being the farthest point yet determined.

If the Vineyard Series does not represent a farther continuation of this Cretaceous, I anticipate that it will be found to have been derived in part from such an extension to the southward of New England.

Against the evidence of the Tertiary elements in the fauna at Gay Head, as that evidence is understood, the presence of a Cretaceous flora cannot be said to furnish conclusive proof as to the age of the Vineyard Series. The present paper is but preliminary. There is need of further and more thorough work in all branches of the paleontology of this series before we shall be able to know its age, whether a large part of the

* Trans. N. Y. Acad. Sci., vol. viii, No. 7, 8, 1889, pp. 177–181.

† W. W. Mather: Rept. 1st Dist. N. Y., 1838, pp. 136, 137; Rept. 1843, pp. 272–742. Hitchcock and Blake: Geol. Map U. S., in the 9th Census, vol. iii. J. D. Dana: this Journal, III, vol. vi, pp. 64–66, 305. C. H. Hitchcock: Proc. A. A. A. S., vol. xxii, pp. 131, 132. Britton: Ann. N. Y. Acad. Sci., vol. ii, pp. 161–182. Trans. N. Y. Acad. Sci., vol. i, pp. 56–58; Trans. vol. iii, pp. 30, 31. F. J. H. Merrill: Ann. N. Y. Acad. Sci., vol. iii, pp. 341–364, pl. xxvii, xxviii.

organic remains have been transported since their first deposition, and, if they have, whence this portion was derived.

U. S. Geol. Survey, November, 1889.

EXPLANATION OF PLATE II.

(Specimens from Gay Head.)

Fig. 1. *Sphenopteris grevillioides* Hr.
Fig. 2, 3. *Sequoia ambigua* Hr.
Fig. 4. *Andromeda Parlatorii* Hr.
Fig. 5. *Myrsine borealis* Hr.
Fig. 6, 7. *Liriodendron simplex* Newb.
Fig. 8. *Eucalyptus Geinitzi* Hr.
Fig. 9. *Eucalyptus Geinitzi*, nut.
Fig. 10. *Eucalyptus Geinitzi*, nut with operculum.
Fig. 11. *Eucalyptus Geinitzi*, flower?
Fig. 12. *Sapindus* cf. *Morrisoni* Lx.

ART. XVII.—*A Review of Dr. R. W. Ells's Second Report on the Geology of a Portion of the Province of Quebec;* with Additional Notes on the "Quebec Group";* by CHARLES D. WALCOTT.

To the geologist interested in the problems presented by the study of the Lower Paleozoic rocks any new data bearing on the geology of the area embraced in the eastern townships of Canada is welcome. It is the region in which Sir William E. Logan worked so long and arduously when building up the "Quebec Group;" also, at a later date, when endeavoring to obtain evidence to sustain his view, that the crystalline rocks were the altered equivalents of the strata referred to the Sillery division of the "Quebec Group." It is the battle ground, where Logan and his adherents have been gradually driven from position to position until, now, there is little left to defend of what seemed in 1863 a well supported position.

The student will find in Dr. Ells's report a careful and detailed description of the geology of the area surveyed and a valuable discussion of the perplexing problem of the "Quebec Group." Not a theoretic discussion, but a discussion based on a careful consideration of the work of those who preceded him in the field, and a thorough study of the typical area in which the "Quebec Group" was first established by Sir William E. Logan and his assistants.

The report, taken in connection with that issued in 1887, sums up the work of the resurvey of the region with the exception of certain areas in the vicinity of Lake Memphrema-

* Geol. and Nat. Hist. Survey Canada, Report for 1887, pt. K, pp. 1–114, Printed in 1889.

gog, and on the western slopes of the Sutton Mountain range, or the northward extension of the Green Mountains of Vermont.

The description of the asbestus mines is continued from the first report,* and a map of the asbestus-producing area accompanies it. A large map of the area surveyed has been prepared and will be published on the completion of the survey of the Laurentian rocks occurring on the north end of the area covered by the N.E. quarter-sheet map of the Province of Quebec.

The area reported upon includes the counties of Megantic, Dorchester, Bellechasse, Levis, Montmagny, and l'Islet and the south line of Quebec or the country to the south and southeast of the city of Quebec and along the St Lawrence river from the Jacques Cartier river, above the city, to Cape Tourmente, below. The group of islands between Quebec and a point opposite St. Thomas were also surveyed, from Orleans Island to Cranes Island, inclusive. The several geologic systems, recognized in this area, include the Devonian, Silurian, Cambro-Silurian (Ordovician), Cambrian, and pre-Cambrian.

Devonian.—The Devonian rocks occur in an outcrop of fossiliferous limestone, which is found on the north bank of the Chaudière river, about midway between the Famine river and the village of St. George. Farther to the northeast, on the road leading to Ste. Justine, a very limited exposure of similar fossiliferous limestone occurs. The breadth of this outcrop is not more than twelve to sixteen feet, and is about the same in length. The outcrop on the Chaudiere river is also of very limited extent. These are the only areas of rock which may be said to belong to the Devonian system that are known to occur anywhere in the area under consideration. Dr. Ells states that the exposures resemble patches of strata which have escaped denudation. A list of thirty species of fossils is given from the Chaudiere locality. (pp. 10K, 11K.)

No rocks that could definitely be pronounced of Silurian age were seen in the area. Some red shales were assumed to represent some portion of the Silurian system. Owing to the character and variety of the exposures, the extent of the areas occupied by these rocks was largely conjectural.†

Cambro-Silurian (*Ordovician*).—The formations pertaining

* Loc. cit.; Ann. Rep. for 1886, pt. J, pp. 15J–70J. Printed in 1887.

† The Silurian rocks, described in the First Report, pp. 7J–14J, includes a small area at the narrows of Lake St. Francis, a large area stretching southwest from Lake Aylmer to Stoke mountain, and a small area in the township of Stoke, west of Stoke mountain. Silurian fossils occur at a number of localities in the limestones. A comparison of these areas, as shown on the map accompanying the report, with the areas colored Silurian, in Logan's Geological Map of Canada, 1864, shows that the latter included large areas of strata referred to the Lower Silurian or Ordovician by Dr. Ells.

to this system, found south of the St. Lawrence river, range from the Hudson, downward, to the Cambrian. The region in which they occur is divided into an eastern and western area; the former including the rocks that occur between the central Archæan anticlinal, or the northward extension of the Green mountains, and the United States boundary, and the latter, the strata situated between the Archæan anticlinal and the St. Lawrence river. The eastern area is the prolongation to the northeast of the great area of Cambro-Silurian rocks, which lies between the Stoke Mountain range and the Cambrian rocks of Lake Megantic and vicinity.* They consist largely of dark gray and blackish, sometimes plumbaginous slates, with grayish sandstones; the former sometimes ochre-spotted and displaying, on weathered surfaces, a characteristic striped or banded aspect. Calcareous rocks are, as a rule, absent, although they have been seen on the upper Chaudiere river.

The western area of the Cambro-Silurian rocks, or those in the vicinity of the St. Lawrence river, present, at several places, many features differing from those of the eastern area. Dr. Ells considers that the formations are, for the most part, presumably of a later age, as indicated by the fossils. At St. Nicholas, fourteen miles above Levis, the contact between the shales and sandstones of the Hudson, and the red, green, and black shales of the Cambrian Sillery terrane is shown on the river beach, near the cliff. The Hudson sandstones contain graptolites and mollusks characteristic of that zone.

The Utica-Trenton outcrop extends nearly three miles and a half, where it is cut off by a line of fault. At Pointe au Platon highly bituminous, brownish gray shales represent the only typical Utica rocks seen on the south side of the river, in this direction The Levis rocks, occurring about Levis, will be spoken of in describing the "Quebec Group."

The strata on the north shore of the St. Lawrence have already been described in the Geology of Canada, 1863. Dr. Ells has added many details and, also, given lists of the fossils occurring in the Trenton, Utica and Hudson terranes.

Dr. Ells made a careful study of the rocks of the Montmorenci Falls, eight miles below Quebec. He decides, from the evidence of the fossils and from the character of the sediments that the conclusions stated by Sir William Logan, in 1863 (Geology of Canada), as to the structure at this place, and subsequently, by Dr. Selwyn, in sundry papers, are clearly maintained. In company with Drs. Selwyn and Ells I carefully studied the geology of Montmorenci Falls and vicinity, in August, 1889, and I fully concur with them in the view that

* See First Report, 14J–23J.

the Trenton limestone rests unconformably upon the Archæan gneiss that forms the bed of the river, at the Falls; and that a fault has carried the Trenton limestone and superjacent Utica shale downward on the east, a short distance northeast of the Falls. The upturned Trenton limestone and Utica shale, forming the bluff between the Falls and the St. Lawrence river, contain characteristic Trenton and Utica fossils. For further details the reader is referred to Dr. Ells's report, pp. 22K–25K.

Cambrian.—The rocks which are regarded as constituting the Cambrian system of eastern Quebec are the extension, to the northeast, of those described by Dr. Selwyn, in the reports of the Geological Survey of Canada for 1886 and 1887. They consist for the most part of hard quartzites interstratified with purple, greenish, and black slates. Limited outcrops of grayish subcrystalline limestone are found occasionally in the townships of Mailloux, Buckland and West Broughton. They are associated with black slates and quartzites. Dr. Ells has also referred the trappean rocks of Broughton and Moose mountains, also certain associated serpentines, to the Cambrian. North of Chaudiere river, the western boundary of the "Lower Cambrian" is said to be unconformably overlapped by the Sillery red slates, conglomerates, and sandstones, the contact of the two sets of rocks being near the village of St. Claire. It is not improbable that some of the strata referred to the Lower Cambrian by Dr. Ells may prove to belong to that system of rocks; but in the absence of fossils it is very difficult to say whether the strata under consideration should be referred to the Cambrian or to some pre-Cambrian series of rocks. From the occurrence of Lower Cambrian fossils (Olenellus fauna), in grayish limestone, interbedded with purple, green and black slates, in Washington County, N. Y., where the rocks containing them occupy a similar stratigraphic position to those under consideration, it is not improbable that a similar fauna will be discovered in the Canadian section. Dr. Ells thinks that a part of the strata referred to the older Cambrian resembles, in many respects, those of the coast series of Nova Scotia, while in part they resemble the lower portion of the Cambrian of New Brunswick. Stratigraphically they occupy a position between the chloritic and micaceous schists of the Archæan and the superjacent strata of the Sillery (page 87K). (See First Report, pp. 23J–29J, for an excellent description of the character of the rocks referred to the Cambrian.)

The Cambrian strata of the Sillery terrane will be noticed under the description of the "Quebec Group."

Quebec Group.—An excellent historical review is given of the literature pertaining to the "Quebec Group," from the

first notice of the rocks in the vicinity of Quebec, in 1827, by Dr. J. Bigsby, to Professor Jules Marcou's essay in 1888. From the study of the literature and of all the original area of the "Quebec Group," including the mapping of the entire area, Dr. Ells concludes that:

"The name 'Quebec Group,' which has for so many years been applied to much of the rocks of this portion of the province of Quebec, has become so misleading and unintelligible in view of the many new facts brought to light concerning its composition and structure, by the study of the past fifteen years and the many changes rendered necessary in consequence, that its further use appears not only undesirable but to a certain extent objectionable. It was applied by Sir W. Logan to a great series of sediments which were deemed to lie somewhere about the horizon of the Calciferous and Chazy formations. Dr. Selwyn and others have, however, since 1876, pointed out that it has been found to embrace rocks ranging from the Pre-Cambrian to the Hudson River or Lorraine, both inclusive. An almost entirely new arrangement of the different formations which make up the group is therefore imperative. In the case of such portions of the original group, the horizon of which has been definitely determined, the proper name of the formation can be readily applied, while in the case of such portions, either distinctly fossiliferous, or closely related areas the exact position of which in the Geological scale may be doubtful, the terms Levis or Sillery, with their system classification, may be retained" (p. 6K).

The author then proceeds to give, after the brief historical sketch, a description of the rocks referred to the "Quebec Group" by Sir Wm. E. Logan.

In the historical review it is stated that the first notice of the rocks of the "Quebec Group" by Sir William Logan, was published in 1845. He then expressed the view that "the rocks on Point Levis come out from beneath the limestone of the St. Lawrence, and belong to an apparently older horizon;" but in a foot note it is stated: "The bulk of evidence points to their superior position, which would make them the equivalents of the Hudson River and Lorraine shale formation."

In the report of progress for 1849, it is stated "that another formation, contemporaneous with the Hudson River of New York, superior to the Trenton limestone, but also far beneath the same Carboniferous deposits, extended from Point Levis to Cape Rosier."

In the Esquisse Géologique of 1855, by Logan and Hunt, the rocks which form the cliffs of Quebec and Point Levis are referred to the Hudson River group, and the series of sandstones and shales, named the Sillery group, are considered equivalent to the Shawangunk or Oneida conglomerate of the New York section.

Mr. Billings's study of the fossils collected from the Point Levis beds proved that the rocks at Point Levis were far below the Hudson River group, and Pre-Trenton in age. These conclusions were first announced by Logan in 1860, and, subsequently, in March, 1861, when the opinion was expressed that "this series of rocks, to which the name 'Quebec Group' is now applied for the first time, represents a great development of strata about the horizon of the Chazy and Calciferous." With the paleontologic proof of the age of the rocks the history of the "Quebec Group" assumed a new aspect. The five divisions of the grauwacke series of 1849 were divided into two portions, the first four of which were united to form the "Levis" formation, while the last was called the "Sillery." The former was subdivided into seventeen parts, having a total supposed thickness of 5,025 feet, at the summit of which was placed the series of greenish sandstones and red and green shales of the "Sillery," which was given a total thickness of 2,000 feet.

In the Geology of Canada, for 1863, pp. 225–297, Logan gives with great detail his views of the structure and stratigraphical position of the several rock formations, which he referred to the "Quebec Group." The group was then divided into the "Levis" and "Sillery" formations, and referred to about the age of the Chazy and Calciferous formations. (Geol. Canada, 1863, p. 233.)

Subsequently (Rep. Prog. 1866, p. 4) Logan divided the "Quebec Group" into three parts—the "Levis" or lower, "Lauzon" or middle, and "Sillery" or upper.

The "Levis" or lower division was distinguished by its general dark and black color and the presence of numerous graptolites and Calciferous-Chazy fossils. The "Lauzon" or middle division embraced the red, green and purple shales of the section above and below Quebec and on the Island of Orleans. The only fossils known were *Obolella pretiosa* and fragments of Lingula. To the "Sillery" or upper division he referred the sandstones and accompanying shales of the original Sillery, with the exception of those separated to form the Lauzon. The strata were unfossiliferous, as far as known. The dark shales, upon which the city of Quebec is built, were referred to the "Levis" and the series of strata referred to the "Levis," "Lauzon" and "Sillery" formed the typical "Quebec Group," in the vicinity of the city of Quebec.

As far back as 1848, Logan held the view that the metamorphic rocks of the eastern townships of Quebec, or the rocks of the Green Mountains of Vermont, in their prolongation into Canada, were altered Hudson River Group strata, with the possible addition of the Shawangunk comglomerates.

In the Report of Progress for 1849, the entire Quebec series of strata were described, and these rocks, in a highly metamorphic condition, were also stated to constitute the mountain belt; and the entire mass of supposed altered and unaltered rocks were referred to the Lower Silurian System.

When the Quebec Group was established in 1861, the great area of crystalline schists and associated rocks of the mountain portion of Quebec were regarded as the metamorphic equivalents of the fossiliferous rocks of the vicinity of Quebec, and hence a portion of the Quebec Group. The Sutton Mountain range, or the Canadian extension of the Green Mountains, was supposed to represent a portion, if not the whole, of the Sillery formation. To the southwest, the Quebec Group was made to include the Phillipsburgh limestones and certain supposed superjacent conglomerates. To the east, in Newfoundland, a great thicknesss of fossiliferous strata were correlated with the Point Levis and Sillery sections.

From the comparison of the fossils occurring in the Point Levis series with those from the Phillipsburgh limestones, Billings concluded that limestone No. 2, of the Point Levis series, was the equivalent of limestone No. 2, of the Phillipsburgh section. Dr. Ells calls attention to the fact that limestone No. 2, of the Levis section, was formed of beds of conglomerate, and could not be relied upon for the determination of the exact stratigraphic position of the zone in the Phillipsburgh section. In summing up all the evidence in relation to the position of the Levis rocks, Dr. Ells says: "It will be seen from all the evidence adduced from so many sources that the true position of the Levis was very conclusively established, both on paleontological and stratigraphical grounds, as distinctly newer than the Calciferous, and this conclusion has been sustained by the most recent examination."

Such is a brief outline sketch of Dr. Ells's historical review of the "Quebec Group" to the year 1868. It is the history of the theoretic evolution of a group of strata based largely upon lithologic resemblances and structural geology.

We have next to consider the breaking down of this elaborately constructed geologic group, built up by the labors of Sir Wm. E. Logan and his associates, Mr. E Billings, Dr. T. S. Hunt and Mr. James Richardson.

Dr. A. R. C. Selwyn began the work of disintegration in the Report of Progress, 1877–'78, pp. 3A–9A, where he shows that the rocks of the Canadian extension of the Green Mountain range, or the Sutton Mountain range and its northeasterly extension, were arranged in an anticlinal, instead of a synclinal form, as supposed by Logan. This removed the keystone upon which the stratigraphic structure of the altered

portions of the Quebec Group was based and with it went the Crystalline Schist Group and the Volcanic Group. The former was referred to a pre-Cambrian Group, probably the Huronian; and the latter, to the Lower Cambrian. "Another source of error, and possibly the most considerable," says Dr. Ells, p. 43K, "was the assumption that the metamorphic rocks of that area must of necessity be the equivalent of the unaltered sediments of the St. Lawrence region, a theory which once suggested, seems to have been unhesitatingly maintained, although for its support, unnecessary inversions of strata, and profound chemical changes were requisite." Dr. Selwyn also pointed out the fact that sandstones, widely differing in age, had been grouped under the Sillery series, and that the rocks of the city of Quebec were cut off from the Lauzon red and green slates by a fault and were not a portion of the Point Levis series.

Dr. Selwyn followed up his first paper with descriptive notes, in 1882,* and a more popular article later in 1882.† A still more recent paper sums up the results of the study of the fossiliferous portion of the original Quebec Group.‡ He here states that no less than four distinct horizons can be recognized, each of which is marked by a coarse band of conglomerate. Three of these bands, numbers 2, 3 and 4, are fossiliferous limestone conglomerate, while one, number 1, is chiefly feldspathic and dioritic, is non-fossiliferous and generally presents the appearance of a volcanic agglomerate or breccia, which he considers pre Cambrian. Number 2 is in the Sillery shales and is of Cambrian age, and contains exclusively a fauna of Cambrian type. Number 3 is the celebrated Point Levis conglomerate, and contains a pre-Cambriam and Lower Cambro-Silurian fauna, while the fauna of the associated shaly bed is exclusively Lower Cambro-Silurian (Ordovician). Number 4 is the Citadel Hill conglomerate of the city of Quebec; the fauna is mixed, but it is chiefly of Trenton-Hudson age, as is that of the associated shales. The mineralogical and lithological characters of the four groups are markedly different, as are the paleontological features.

Dr. Selwyn describes the structural geology, recognizing the great fault and its branches, which have broken up the formations in the vicinity of Quebec, and, also, the folds on the Point Levis side which Sir William Logan mapped so carefully in his study of the geology of this region.

Dr. Ells's careful survey and mapping of the area embracing the typical strata of the "Quebec Group," has demonstrated

* Rep. Prog. Geol. Survey Canada, 1880–'81–'82.
† The Quebec Group Geology, Trans. Roy. Soc. Canada.
‡ Science, vol. ix, p. 267, 1887.

the correctness of the views advanced by Dr. Selwyn and has also added materially to our own knowledge of the geologic structure and stratigraphic succession of the beds forming the unaltered series of the "Quebec Group." He has shown that the order of succession of the strata was inverted by Logan, and that the Levis series is conformably superjacent to the Upper Sillery (Lauzon of Logan), and that the Lower Sillery forms the base of the section in the vicinity of Quebec.

The study of the relations of the Levis to the Sillery, at Levis, is a beautiful piece of stratigraphic geology and a most careful and conscientious work. I accompanied Dr. Ells over the area, in August, 1889, and fully concurred with him in his views of the structure. The surface outcrops are essentially as mapped by Sir Wm. E. Logan, in 1863. The radical difference between the interpretation of the latter and Dr. Ells is that Dr. Ells places the red Sillery strata below the Levis and not above, as was done by Logan. Dr. Ells recognizes four anticlinal axes, two of which, at least, are completely overturned. One of these is so well shown that I obtained a very good photograph of it, on the road leading up the cliff, 300 yards south of the lower ferry at Levis. Beneath the Levis strata the red shales of the Sillery are shown, and the synclinals of Levis strata rest in the red shales of the Sillery. The tracing of the anticlinals and synclinals was by means of the stratification and the occurrence of the sub-faunas in the graptolitic shales of the Levis terrane. On the eastern margin of the Levis beds an overturned synclinal has placed the red shales of the Upper Sillery upon the graptolitic shales of the Levis. In the upper beds of the Sillery a few graptolites and brachiopods indicate the intimate paleontologic relations of the upper portion of the red Sillery shales with the dark graptolitic shales of the Levis terrane. A list of the graptolites at each locality is given by Dr. Ells, with a discussion of the stratigraphic relations of the several fossiliferous zones.

The strata of the city of Quebec were referred to the Levis series by Logan and to the pre-Potsdam Taconic by Jules Marcou. Dr. Ells gives a list of forty species of fossils, obtained from the shales and interbedded dark limestone, that were collected by Messrs. Giroux and Ami, and determined by Mr. H. M. Ami. The fauna is essentially Middle Ordovician or Trenton-Utica, and proves conclusively that the Quebec city strata are neither Levis, nor pre-Potsdam. Prof. Lapworth thinks that the graptolites indicate the Lower Trenton, and Mr. Ami considers the *Monticuliporoids* to be of Lower Trenton age.

The limestone conglomerates of the "Quebec Group" have been a fruitful source of confusion since they were described

by Logan in 1863, in connection with the lists of fossils determined from them by Mr. Billings. According to Logan, the conglomerate in the Sillery series was the highest of the conglomerate beds; the fossils in its bowlders were not described. The Levis conglomerates were interbedded with the graptolitic shales, and contained fossils in the matrix and also in the bowlders imbedded in the matrix or paste. Mr. Billings identified the fossils, but did not distinguish between those found in the paste and those obtained from the bowlders. This led to a mixing up of the Upper Cambrian and Lower Ordovician faunas, such as is unknown elsewhere. Mr. Billings never felt assured that the fossils occurred *in situ* in the paste or matrix of the conglomerate, and hence he correlated the Levis beds with the upper or Chazy zone of the Phillipsburgh section, under the name of Upper Calciferous, instead of with the central or true Calciferous strata of the Phillipsburgh section. The conglomerates of the Quebec city rocks were not known to contain fossils when described by Logan.

Dr. Ells describes three zones of limestone conglomerates (p. 83K). 1st. Those of the Upper Sillery interbedded in the green, black and reddish or purple shales; 2d, those of the Levis series, and 3d, those of the city of Quebec. The first or lower zone contains the Olenellus or Lower Cambrian fauna; the second, Potsdam and Calciferous fauna, and the third, the Lower? Trenton fauna. In the first no fossils have been found in the paste or matrix. In the second Dr. Ells quotes Mr. Billings as follows: "All the specimens described in this article were found in the conglomerate limestones near Point Levis, opposite Quebec. It is not yet decided whether the fossils occur in the bowlders of the conglomerate or in the matrix." In the succeeding paragraph Sir Wm. E. Logan is quoted as saying: "I am satisfied, notwithstanding the conglomerate aspect of the bands of rock which contain our new fossils, that the fossils are of the age of the strata."

Page 39K. "It follows from a consideration of the facts just presented . . . that the rocks of Point Levis, viz: the Point Levis conglomerate limestone and graptolitic shales, are at least 2000 feet above the true Calciferous formation." It is stated in the next paragraph that from the known data the Levis conglomerates and associated graptolitic shales are superior at least to the Upper Calciferous of the Phillipsburgh series.

Of the collections made from the Levis conglomerates, during Dr. Ells's survey, he says (p. 56K): "Other collections were made from the interstratified beds of conglomerates, but as these were in all cases from the limestone pebbles, and not from the matrix, their value in determining exact horizons

from these rocks is doubtful." This statement is repeated on page 81K.

When first reading the description of the Point Levis rocks in 1874, I was puzzled by the mixing of the faunas in the lists published by Mr. Billings and the statement made by Sir Wm. E. Logan, that the fossils were from the matrix. On reaching Quebec, in August, 1889, I took the first opportunity to examine the lowest bed of limestone conglomerate back of St. Joseph de Levis and northwest of the Catholic cemetery. Dr. Ells accompanied me. As we crossed the ridge I picked up a loose bowlder full of Potsdam or Upper Cambrian fossils. A second bowlder was found embedded in the matrix and then several more, some of which were three feet in diameter. The matrix is a hard, gray, impure limestone that occurs at this point in a solid band, that we traced 500 feet or more. In the matrix I found the Calciferous fauna was represented by *Obolella* sp.? *Orthis* sp.? *Camerella calcifera* Billings, *Ecculiomphalus canadensis* Billings, *Ecculiomphalus intortus* Billings, *Ophileta complanata* Vanuxem, *Pleurotomaria canadensis* Billings, *Pleurotomaria* sp.? *Orthoceras*, 4 sp. undet., *Ceraurus? apollo* Billings, *Ceraurus eryx* Billings, *Bathyurus bituberculatus* Billings, *Bathyurus quadratus* Billings.

In a bed of limestone, fifty feet higher in the section, I found, in addition to the preceding, the following: *Bathyurus cordia* Billings, *Bathyurus oblongus* Billings, *Amphion Caleyi* Billings. In the succeeding band of limestone conglomerate *Orthis porambonites* Pander occurs.

A large number of specimens were obtained from the bowlders embedded in the limestone containing the fossils of Calciferous age, among which I have identified *Camerella calcifera* Billings (?), *Agnostus americanus* Billings, *Dicelocephalus magnificus* Billings, *D. Oweni* Billings, *D. Belli* Billings, *Arionellus subclavatus* Billings, *Menocephalus? Sedgwicki* Billings, and *Illænurus illænoides* Billings (sp.). Other species occur, but the preceding list is sufficient to indicate the fauna of the Upper Cambrian or Potsdam zone.

Dr. Ells accepted the view that the Calciferous fauna occurred *in situ* in the matrix of the conglomerate, and that the bowlders containing the Potsdam fauna were derived from preëxisting strata.* In the next band of conglomerate, above that which forms the ridge on the north side of the cemetery, the matrix also carries Calciferous fossils, and they are also abundant in the bowlders. In a search of two days I failed to find a Potsdam fossil at this horizon. From Dr. Ells I learned that nearly all the fossils described by Mr. Billings came from

* This view was added in a foot note at the close of Mr. Ami's list of the species on Dr. Ells's return to Ottawa in October.

the lower zone, and we found traces of extensive collecting. With this exact data I was enabled, at once, to correlate the lower belt of limestone and conglomerate with the central band of the Phillipsburgh section, where an identical fauna occurs 1000 to 1110 feet above the recognized Potsdam sandstone.*

This zone is 600 feet beneath the zone of "*Maclurea ponderosa*," where Mr. Billings placed the Levis conglomerates. The long period of uncertainty regarding the true mode of occurrence of the faunas in the Levis calcareous rocks is now terminated, and a fixed datum point secured for comparison with the known section on the shores of Lake Champlain.

Dr. Ells quotes the greater part of the conclusions contained in Professor Charles Lapworth's instructive paper on the graptolites of the "Quebec Group."† In this the graptolitic zone of the Levis shales is correlated with the typical Arenig of Great Britain and the Phyllograptus beds of Scandinavia. The graptolites of the Citadel Hill or Quebec City strata are correlated with the middle Llandeilo zone of Great Britain.

The stratigraphic succession, as determined by Dr. Ells, is as follows (p. 64K):

1. Black, green and gray shales, with thick bands of grayish and sometimes yellowish-white quartzose sandstone and occasional thin bands of limestone conglomerate.

2. Greenish, grayish and blackish, and occasional bands of reddish or purple shales, with thin layers of gray sandstone. Annelid trails (fucoidal markings of Ells) are numerous on the greenish shales. On the south shore of the St. Lawrence, below Levis and also on the south shore of the Island of Orleans, beds of conglomerate occur at about this horizon, in which the Lower Cambrian fauna occurs (p. 65K).

3. Bright-red shales, with thin bands of greenish and gray shale.

4. Red, greenish-gray and black shales, with interstratified Sillery sandstones.

Obolella pretiosa in the upper part, near Sillery, and on the south side of the river, *Obolella pretiosa*, *Protospongia fenestrata*, *Phyllograptus typus*, *Tetragraptus serra* and *Lingula quebecensis*.

5. Levis shales and conglomerates of Point Levis.

6. Black and grayish-striped or banded shales, with the black and graphitic shales and limestone of the Arthabaska and Somerset synclinal, the latter not appearing in the Quebec and Point Levis sections.

7. The black or brownish bituminous shales and limestones of

* During the summer of 1888 I discovered the Potsdam sandstone beneath the limestones of the Phillipsburgh terrane, on the shore of Missisquois Bay, one mile south of the wharf at Phillipsburgh. The section was measured from this horizon to the Chazy-fauna zone, and then to the Trenton limestone.

† Trans. Roy. Soc. Canada, 1886, section iv, pp. 167–184.

the city of Quebec and northwest side of the Island of Orleans. The contained fauna is of Trenton-Utica age.

From the Cape Rouge section and the strata on the south side of the St. Lawrence, Dr. Ells concludes that the evidence afforded by the stratigraphy and the graptolites, determined by Professor Lapworth, is sufficient to refer the Sillery rocks of 1, 2, 3 and 4 of the section, to the Cambrian system, and the Levis beds (5) to the Lower Ordovician.

The thickness of the Sillery and Levis rocks are not given; but Dr. Ells told me that the measurements given by Logan were as nearly correct as could be determined. These were 2000 feet for the Levis shales and 5000 to 6000 feet for the Sillery series as now known.*

The *Obolella pretiosa* ranges through from 1500 to 2000 feet of the Upper Sillery, and the lower conglomerate, of 2, occurs in the lower portion of this series. The Cape Rosier *Dictyonema sociale* zone is regarded as the lowest of the graptolitic zones, and to indicate the horizon of the Tremadoc terrane of Great Britain. The Cape Rosier beds are referred to the Upper Cambrian by Professor Lapworth and Dr. Ells, but with our present knowledge of the Cambrian in America, I would refer them to the Lower Ordovician or to the Lower Calciferous. The occurrence of the typical Calciferous fauna within one hundred (100) feet of the base of the Levis series, at St. Joseph de Levis, points very strongly to considering the graptolitic fauna of the Upper Sillery to be of Calciferous age, if a comparison is made with the Phillipsburgh section.

Dr. Ells refers the Sillery series to the Cambrian and in this I mainly agree with him, except that the upper portion is evidently a passage series between the Cambrian and Ordovician. On lithologic and stratigraphic evidence the line would be drawn at the summit of the red shales. On paleontologic evidence, as furnished by the graptolites, I would include the upper portion of the Sillery red, and green beds in the Ordovician, as I think they are above the typical Potsdam zone of America.

It will be recalled that Dr. Ells stated that the Sillery beds rested unconformably upon the slates, quartzites, etc., which he refers to the Lower Cambrian. He mentions that, in this lower series, beds of gray subcrystalline limestone occur. It may be that we here have the source from which the limestone conglomerate of the Sillery was derived, which contains the Olenellus fauna. This would be in accordance with the mode of occurrence of the Olenellus or Lower Cambrian fauna to the southward, in Vermont and eastern New York.

Dr. Ells's conclusion as to the value of the term "Quebec

* This transfers a considerable portion of the strata originally referred to the Levis to the Sillery.

Group" in geologic nomenclature has already been quoted, *ante* p. 105. After an examination of the typical area, in company with Drs. Selwyn and Ells, and with the latter, the Sutton Mountain anticlinal and superjacent volcanic rocks and so-called Lower Cambrian rocks, I agree with the conclusions given, and think that the term "Quebec Group" had best be dropped from geologic nomenclature To the one who would use the term I will ask, to *which* of the following groups would you apply it?

1. The Trenton-Utica strata of the Citadel Hill of the city of Quebec?
2. The Lower Ordovician strata of the Levis Terrane?
3. The Upper and Middle (?) Cambrian strata of the Sillery Terrane?
4. The Lower Cambrian strata flanking the Sutton Mountain range? or,
5. The pre-Cambrian post-Laurentian strata of the Sutton Mountain anticlinal?

Until it is determined which of the above shall receive the name, it appears best not to use it indiscriminately.

Dr. Ells's suggestion to use the name "Levis" for the local development of the Calciferous terrane about Quebec, and the name "Sillery" for the passage beds and Cambrian strata of the St. Lawrence valley, in the vicinity of Quebec, is an admirable one and worthy of imitation by those geologists interested in the advance of geology in America

Pre-Cambrian.—The crystalline schists of the Sutton Mountain anticlinal and its northeasterly extension are unconformably subjacent to the overlapping slates and quartzites of the supposed Lower Cambrian, and form the oldest known rock series in the district. Dr. Ells describes their geologic distribution, and the character of the micaceous, chloritic and talcose schists, as found in several sections crossing the anticlinal.

Under the head of "Crystalline and Igneous Rocks," p. 93K, intrusive granite and diorite are described. The diorite forms a chain of hills that extend from the Vermont boundary, near Lake Memphremagog, to north of the Chaudiere river. The diorites are closely associated with the serpentines and all are referred to the Cambrian system. The areas of serpentine are quite large and of great economic importance, owing to the numerous veins of asbestus found in them, especially in the townships of Thetford, Coleraine and Ireland. A short description of the mines is given, with the product of several of the larger ones (pp. 106K–112K). A short description of the economic minerals notes the presence of gold on the Chaudiere river and the exploration for it; also the indications and mining of copper, and the occurrence of iron ores, soapstone, limestone and building stones.

Surface Geology.—The features of the surface geology to which special attention was directed had reference to the course of the ice-flow and the distribution of bowlders and other drift. The conclusion is reached that the St. Lawrence river extended, in pre-glacial times, from 25 to 40 miles east of its present valley, and that its channel, as well as that of many tributary streams, Etchemin, Chaudiere, etc., was pre-glacial and of considerable antiquity. Large areas of sand and clay occur, and rock exposures are infrequent in the broad, flat country east of the St. Lawrence. The pre-Cambrian ridges abruptly rise from 1400 to 1600 feet, and then the surface slopes gradually to the St. John river basin near to the Maine boundary.

Dr. Ells thinks that the theory of local glaciers instead of a great ice cap appears to be supported by the direction of the striæ following the river valleys and the prevailing slopes from the central highlands. This may be true, but if considered as the closing phenomena of the glacial period after the great ice sheet had retreated, the local glaciation is readily explained; and the theory of the cap still remains to explain the great glaciation observed to the south, in New England, New York, etc.

The distribution of the bowlders of Laurentian rocks over the surface is explained by submergence and floating ice carrying the bowlders from the Laurentian hills south. Elevated terraces are cited to show submergence.

A systematic list of the fossils referred to in the report is given by Mr. Henry M. Ami at the close of the report.

Art. XVIII.—*Measurement by Light-waves*;* by Albert A. Michelson. With Plate III.

Almost every accurate measurement of any physical quantity involves and usually depends upon a measurement of length or of angle. In linear measurements the microscope is usually employed, and in angular measurements the telescope.

The use of these instruments depends entirely on the properties of the optical media in their relation to *light-waves;* so that in fact light-waves are now the most convenient means we have for making accurate measurements; and it can readily be shown that it is the very minuteness of the waves which permits the extraordinary degree of accuracy already attained in the use of optical instruments.

* A lecture delivered at the Jefferson Physical Laboratory of Harvard University.

It is especially with a view of testing whether it is not possible to utilize these light-waves to even greater advantage that I desire to institute a comparison between the telescope and microscope on the one hand, and the refractometer on the other; to point out some remarkable analogies in their fundamental properties; and to illustrate a few cases in which the last-named instrument appears to possess a very important advantage over the others.

In the microscope (and the same remarks can be modified to apply equally well to the telescope) the performance depends largely on the quality of the objective. Let this be supposed a single perfect lens. Very elementary considerations will show that the magnifying power of the lens is $\frac{\sin \alpha}{\sin \beta}$, where α and β are the apparent semi-diameters of the lens viewed from the object and image respectively; and this is greatest when $\alpha = 90°$ and then $M = \frac{1}{\sin \beta}$. But it is well known that the image of a luminous point consists of a series of small concentric rings of light; and it is easy to show that the radius of the first ring is the wave-length divided by 2 sin β, or $\frac{1}{2}\lambda M$. This means that the indistinctness of the image grows in exactly the same proportion as the magnifying power.

Now a microscope is commonly used: 1st, to separate into their elements closely packed groups of minute objects; 2d, to recognize the forms of minute objects; 3d, to locate the positions of minute objects. In the first case and also the second, it is manifestly useless to increase the magnification beyond the limit where interference fringes are just perceptible. In the third case, however—were it not for the attendant decrease in the illumination—it would be advantageous to go beyond this point—so far in fact that the apparent width of the fringes is about a hundred times that of the cross-hairs in the eye piece. But long before this stage is reached the illumination is much too feeble for distinct vision. (If the lens is in any way imperfect, the imperfections are of course much magnified.)

With the first-named requisites of telescopes and microscopes, namely, "resolution" and "definition," we have no further concern. It is especially with regard to the third requisite—which may be termed "accuracy"—that I wish to institute a comparison between these instruments and the refractometer.

As there appears to be a slight confusion in regard to these terms, it may not be amiss to propose the following:

Confining the attention to the objective alone,

Let B = diameter of objective.
F = focal length of objective.
α = apparent semi-diameter of objective viewed from the object.
β = " " " " " image.

d = smallest distance between lines which can be clearly "resolved."
λ = wave-length of the light employed.
b = breadth of the diffraction fringes with this kind of light.
M = Magnification.
R = Resolution.
D = Definition.
A = Accuracy.

Then if M is the ratio of size of image to object,

$$M=\frac{\sin a}{\sin \beta}$$

The *resolution* is measured by the closeness of two lines which can be clearly distinguished or "resolved." Let us therefore put

$$R=\frac{1}{d}$$

Now two lines are clearly distinguishable when the central fringes of their images are separated by the width of one fringe. The actual limit at which the resolution disappears may be anywhere between b and $\frac{b}{2}$. (See "Wave Theory," Lord Rayleigh, Enc. Brit.) But it can readily be shown that $b=\frac{\lambda}{2 \sin \beta}$ and $d=b/M$, hence,

$$R=\frac{2}{\lambda} \sin \beta.$$

The *definition* of an objective is measured by the ease with which the forms of minute objects may be recognized. Thus, were it not for diffraction, D would be simply proportional to M. But for a given magnification the form of the image is clearer, or the definition greater as the fringes are narrower; hence, we may put

$$D=\frac{M}{b}=R$$

Definition is not capable of being so precisely formulated as Resolution, and would undoubtedly vary with the form of the object, its nearness to other objects, etc. In view of these uncertainties it would scarcely be worth while to introduce a constant coefficient in the last equation.

The error of setting of the cross-hairs of an eye-piece on the middle of a diffraction band of sufficient width will be b/e where e is a constant not far from 100, and the corresponding error in distance would be $b/e \div M$. This smallest *measurable* distance is therefore e times as small as the smallest *resolvable* distance; hence,

$$A=eR.$$

These formulæ may be applied to the microscope (in which case the maximum values correspond to $a=90°$), or to the telescope (in which a is nearly zero, and angular measurements alone are of importance). Accordingly we obtain the following:

	Microscope.	Telescope.
M =	$1/\sin \beta$	F
R =	$2/\lambda$	B/λ
D =	$2/\lambda$	B/λ
A =	$e2/\lambda$	eB/λ

The formulæ for microscopes apply when the object is very near the lens. They show, first, that with a microscope of given length the magnifying power depends on the smallness of the objective and on nothing else; second, that the resolution, definition and accuracy (upon which the usefulness of a microscope chiefly depends) are the same for all microscopes, no matter how large the objective may be, or how great the magnifying power, provided the latter be sufficient to show diffraction fringes; third, that these qualities vary inversely with the wave-length of the light employed.

There seems to be a prevailing impression that a microscope may have a high resolving power with but moderate definition and *vice versa*. This may be due to the difficulty in giving an exact signification to the terms. If those here employed be admitted it is evident that the two qualities must go together.

In the telescope the size of the image and hence the magnification depends entirely on the focal length. The resolution is in this case the reciprocal of the smallest angular distance which can be clearly distinguished. It increases with the diameter of the objective and inversely with the wave-length. These formulæ may also be applied to the revolving mirror as used in galvanometers, etc., except that in this case the accuracy is doubled, so that

$$A=2eB/\lambda.$$

The foregoing statements must be understood to refer to theoretically perfect lenses. If the lenses be imperfect the ratio of their performance to that of a perfect lens may be expressed by a constant depending on the accuracy of the surfaces and the nature of the glass.

The first named qualifications depend on the accuracy with which all parts of the lens contribute to make the elementary waves reach the focus in exactly the same phase. But this is not at all necessary for "accuracy." For this purpose it would be as well to entirely annul the central portions of the lens (or mirror) leaving only an external annular ring; or better still only *two small portions* at opposite ends of a diameter need be used; and this too without any sacrifice of accuracy but on the contrary a very considerable gain. For it is now possible to increase the size of the interference fringes up to any limit without affecting the light; and the result is exactly the same as could be obtained with a perfect microscope of infinite magnifying power with an infinitely bright source of light.

These two small portions to which the lens is thus reduced need not be curved, but may be either plane mirrors or prisms. *Thus the telescope or microscope will have been converted into a refractometer.*

The details of the various forms which the instrument may take, their classification, and their older and better known analogues, are shown in the diagrams, Plate III.

Description of Plate.

In the first four groups the paths of the two pencils are equal.

Group I.—Waves emanate at a point and converge at another. Nos. 1 and 3 are the types; 2, represents Fresnel's mirrors; 4, Billet's half-lenses; and 5, Fresnel's bi-prism. In this group the diminution in intensity is the same as in the microscope.

Group II.—In this and the succeeding groups a pencil of rays divides at a plane surface and reunites at another. No. 1 is the type (a simple microscope objective). Nos. 2 and 3 are forms appropriate for linear measurements; 4, 5, 6 and 7, for differential measurements. 4 and 5 show the essential part of the refractometer of Jamin and of Fresnel respectively. (The latter does not belong to the group, but serves as a type for 6 and 7.)

Group III.—In this group the pencils retrace their path, and reunite at the same surface, *o*, where they separate. Fig. 1 is the type for 2 and 3. These figures represent the original form from which the others have been derived.* They may be used for absolute or differential linear measurements.

Fig. 4 is the type for 5 and 6 which are appropriate forms for angular measurements; in fact just as the angular motion of the mirror *mm* of 4 is detected by the motion of the image at *o*, so that of the mirrors *mm* of 5 and 6 is detected by the motion of the interference fringes at *o*.

* See "Interference phenomena in a new form of refractometer," A. A. Michelson, this Journal, Art. xlvi, p. 395, 1882.

These forms may also be used for differential measurements with the advantage that the displacement is double that of the corresponding instruments of Group II.

Group IV.—This group is useful only in cases where the velocity of light varies with the direction according as this is positive or negative. The only application thus far made is in the problem of the speed of light in moving media. For this purpose it is very essential that no accidental variations in the two paths should have any effect. Accordingly each pencil is made to return by the *other's* path. Of this group fig. 1 is the type; 3 is the form used by Fizeau in his celebrated experiment; and 2 that employed in a recent repetition of the same work.*

Group V.—In this case the paths of the two pencils are unequal. Figs 1, 2 and 3 represent various forms of grating spectroscope, of which the last is a concave grating in which the spectral image coincides with the slit. The transition to the corresponding refractometer forms, 4 and 5, is apparent.

Linear Measurements.

It may be assumed from experiments made by Professors Rogers and Morley that with the most accurate and powerful microscope at their command, and with the very best conditions as regards the object observed and its illumination, the utmost attainable limit of accuracy of a setting of the cross-hair of the microscope on a fine ruled line was about two millionths of an inch or about a tenth of a light-wave. Now it is usually granted that the cross-hair of an eye-piece can be set upon the middle of an interference fringe, if this is sufficiently broad and clear, with an error of about one thirtieth of a fringe. In the refractometer this would mean an error in distance of only one-sixtieth of a light-wave.

The following is a record of the results of three direct measurements of the length of a wave of green light emitted under the proper conditions by incandescent mercury vapor. I have been fortunate in obtaining the first series from observations by Professor Morley, whose results with the microscope have just been quoted. The second series was taken by myself; and the third, by an observer who had no previous practice in this kind of measurement. In all cases the scale readings were unknown to the observer.

(1)	Δ	(2)	Δ	(3)	Δ
119·0	2·0	118·5	0·0	117·0	−2·0
117·5	0·5	119·0	0·5	118·5	−0·5
117·0	0·0	119·5	1·0	118·5	−0·5
116·0	−1·0	118·0	−0·5	122·5	3·5
115·5	−1·5	119·5	1 0	120·5	1·5
117·5	0·5	119·0	0·5	120·5	1·5
117·0	0·0	118·5	0·0	119·0	0·0
117·0	0·0	119·0	0·5	118·0	−1·0
117·5	0·5	117·5	−1·0	117·5	−1·5
117·5	0·5	116·5	−2·0	118·5	−1·0
Means: 117·15	0·65	118·50	0·70	119·05	1·30
Error in waves:	0·0056		0·0059		0·0110

* "Influence of Motion of the Medium on the Velocity of Light:" Michelson and Morley, this Journal, xxxi, May, 1886.

It is evident therefore that one-thirtieth of a wave is much too large an estimate of the average error in a setting, and that it is in fact less than a hundredth of a wave, corresponding to an error in distance of one two-hundredth of a wave, or about one ten-millionth of an inch.*

Angular Measurements.

In the measurement of angles the microscope is replaced by the telescope. From considerations quite analogous to those employed in the former case, it can be shown that the limit of accuracy attainable in the estimation of angles involves an error of about one tenth of a second for a ten-inch glass. Let this be compared with the performance of the refractometer, 5, Group III, the distance *mm* being also ten inches. If the line joining *mm* be rotated in the plane of the figure, there will be a corresponding difference in path. Taking one hundredth of a fringe as the smallest perceptible displacement, this would correspond to a distance of one two-hundredth of a wave, or in ten inches, to an angle of one five-hundredth of a second.

In the use of the revolving mirror—as in galvanometers, gravity and torsion balances, etc.—the accuracy can be increased only by making the surface, and therefore also the moment of inertia, of the mirror larger; but here we may make the mirrors insignificantly small and yet—with the same distance between the outer edges—increase the accuracy at least twenty-fold. It is important to note that any motion of the line joining the two mirrors as a whole, or even a tilting of the mirrors in a plane at right angles to this line, has absolutely no effect on the central part of the fringes. Fig. 3, plate III, shows the application of this method of angular measurement to the testing of the ways of a dividing engine, comparator, etc.

Spectrometer Measurements.

It is not at first evident that there is any resemblance between the spectroscope and the refractometer. A consideration of the figures under Group V will show that there is a close analogy. Exactly as in the case of mirrors and lenses, we may here too sacrifice resolution and definition by using only the extreme portions of the surface, with an actual gain in accuracy. To compare numbers, it appears that the probable error in the measurement of a wave by a grating with an ex-

* It may be possible with the aid of photography to increase this degree of accuracy many times. Thus, the curve representing the brightness of the fringes is a simple sine function, fig. 1, plate III. Now if the intensity at the minima is really zero, and a photographic plate be very much over-exposed to the image of such interference fringes, the resulting curve would be represented by fig. 2, plate III, and it is evident that the error in setting on the darkest points (the brightest on the negative) must be far less than by direct observation.

treme difference in path of about 250,000 waves is about one part in half a million.

It is believed that in some experiments recently published* this degree of accuracy has been attained with a difference of path only one-tenth as large, and exceeded with twice this number. But there is no reason to think that (in some cases at least) the limit of visible interferences will be reached even with two or three hundred thousand waves. This means ultimately an error of something like *one part in twenty millions* in the estimate of a single wave-length.

Thus it appears that it is possible to construct a single instrument of a few pieces of plane glass which can combine the functions of a microscope, a telescope and a spectroscope; and that *for purposes of measurement* may be made to far surpass these instruments in accuracy.

ART. XIX.—*On Lansfordite, Nesquehonite, a new Mineral, and Pseudomorphs of Nesquehonite after Lansfordite;* by F. A. GENTH and S. L. PENFIELD. With Plate IV.

UNDER the name lansfordite one of us† described a new mineral which had been discovered in October, 1887, by Messrs. D. M. Stackhouse and F. J. Keeley in one of the anthracite mines in the neighborhood of Lansford, near Tamaqua, Schuylkill Co., Pa. The specimens collected at that time, which were entirely uniform in appearance, occurred as incrustations and in the form of stalactites showing some crystalline faces. They had throughout their whole mass the appearance of paraffine, a distinct cleavage, probably basal as will be shown later on, and a vitreous luster. The specific gravity was found to be 1·692 (Keeley) and 1·54 (Stackhouse), the former being probably too high owing to a slight decomposition caused by boiling the specimen in water. An analysis by Mr. Keeley gave the following formula: $3MgCO_3 . Mg(OH)_2 . 21H_2O$, corresponding to

	Found.	Calculated.
CO_2	18·90	19·19
MgO	23·18	23·25
H_2O	57·79	57·56
	99·87	100·00

In the month of June, 1888, Mr. Keeley paid a second visit to the locality in order to secure the balance of the lansfordite,

* "On the feasibility of establishing a light-wave as the ultimate standard of length:" Michelson and Morley, this Journal, xxxviii, Sept., 1889.

† Dr. Genth: Zeitschr. Kryst., xiv, 255.

and after a great deal of trouble found the locality and collected every available fragment. Altogether there may have been fifty pieces, the total weight of which did not exceed half a pound. The exact locality is in No. 1 Tunnell at Nesquehoning, four miles from Lansford. All the specimens of the second lot showed a remarkable change. They were not like the first, uniform in appearance, but had suffered partial decomposition, showing at the base of the stalactites and incrustations, where they were attached to the carbonaceous shales, groups of transparent, radiating, prismatic crystals, individuals of which penetrated or were wholly covered by the material of the still unaltered lansfordite. During the period of a few months after collecting the second lot at summer temperature, when the thermometer ranged about 90° F., almost all of the lansfordite specimens suffered a still further decomposition, being converted into an opaque white cryptocrystalline or chalk-like mineral, and this change has been continually going on, so that at the time of writing this article there is not a single specimen of wholly unaltered lansfordite in our possession.

The clear crystals, which we have just mentioned, proved on examination to be a new mineral, having the composition $MgCO_3 . 3H_2O$, to which we have given the name Nesquehonite, after the locality where the mineral was found, the Nesquehoning Mine being one of the best known in Pennsylvania.

In the following pages in addition to the nesquehonite we shall describe a crystallized artificial salt of the same composition. It will also be shown that the altered stalactites are pseudomorphs of nesquehonite after lansfordite and from the crystal faces on the stalactites we have been able to make out the crystallization of the original lansfordite which is at present only known as pseudomorphs. In making the investigation the chemical work was all done by Dr. F. A. Genth in Philadelphia, Pa., and the crystallographic work by S. L. Penfield in New Haven, Ct.

Nesquehonite.

The crystallization of nesquehonite is orthorhombic. The prismatic crystals occur occasionally isolated but usually in radiating groups, showing only one free end which sometimes projects into a cavity but more often penetrates and is covered with the material of the lansfordite. Individual crystals are frequently over 10^{mm} long and 2^{mm} thick, and show at the free end either a basal plane alone or the base in combination with a brachydome. The faces in the prismatic zone are always deeply striated parallel to the vertical axis and consequently the crystals have their vertical edges rounded and are frequently much distorted owing to the prominence of one or more of the verti-

cal faces. On the reflecting goniometer the faces in the prismatic zone frequently yield an unbroken band of reflections of the signal with more prominent parts indicating the position of a unit prism *m*, 110 and a brachypinacoid *b*, 010. No reflections were ever obtained from a macropinacoid and what appears to be that face on many of the crystals is probably a rounding off of the obtuse edge of the prism owing to oscillatory combination of the prismatic faces. No sharp reflections were obtained in this zone from either prisms or brachypinacoids, but by measuring from the most prominent reflections approximate values were obtained for the prismatic angle. The faces at the ends of the few crystals at our disposal yielded better results, the dome faces giving fair reflections of the signal so that the angle could be measured with a good deal of accuracy. The basal plane gave in all cases a double reflection of the signal, the two reflections being just about 1° apart, while the reflection from a simple basal plane, just truncating the brachydome, should be midway between them This vicinal development of the basal plane can be detected on all of the crystals. The cleavage of the mineral is quite perfect parallel to the prism and less perfect parallel to the base. Parallel to the prism the mineral breaks with a splintery, almost fibrous fracture and no success was obtained in developing large flat prismatic surfaces by cleavage; with larger crystals and more material one might obtain cleavage prisms which on the goniometer would give a very correct measurement of the prismatic angle, but in trying to obtain such prisms, splinters were always loosened which were more or less displaced from their proper position and yielded multiple reflections of the signal so that we could not tell from just what reflection to take the reading of the goniometer. The best measurement of the prismatic angle was however obtained from one of these cleavage prisms, and although not as good as one would desire, it is the best that the material at our disposal afforded.

The forms which have been identified on the crystals are:

c, 001, *O*; *b*, 010, *i*-$\bar{1}$; *m*, 110, *I*; and *d*, 011, 1-$\bar{1}$.

The arrangement and development of the faces is shown in fig. 1.

For fundamental angles the following were chosen:

$d \wedge d$, $011 \wedge 0\bar{1}1$ $= 49°\ 6'$
$m \wedge m$, $110 \wedge 1\bar{1}0$ (both cleavage) $= 65\ 36$

from which the following axial relation is calculated:

$$\breve{a} : \breve{b} : c = 0{\cdot}645 : 1 : 0{\cdot}4568$$

The following angles were measured independently on six different crystals in addition to the fundamental angles given above:

	$d \wedge d$	$d \wedge b$	$m \wedge m$	$m \wedge m$
Calculated	49° 6′	65° 27′	65° 36′	114° 24′
Measured	49 6	65 28	66 30	113 30
	48 57	65 8	66	115 5
		65 15	66 4	
		65 10		
		65 51		
		66 0		

The prismatic angles vary considerably from the fundamental values, which would be expected from the nature of the crystals, and consequently the value of the $\breve{a}$ axis 0·645 can only be regarded as approximate.

The optical properties indicate decidedly orthorhombic symmetry. The plane of the optical axes is the base, the brachy-axis being the acute bisectrix and axis of greatest elasticity; the double refraction is therefore negative and is rather strong. From a small plate $1\frac{1}{2} \times 4^{mm}$ cut parallel to the macropinacoid the divergence of the optical axes was measured on a large Fuess axial angle apparatus and found to be:

$2E = 83° 55'$ for red Li flame.
$2E = 84\ 15$ for yellow Na flame.
$2E = 84\ 22$ for green Th flame.

Five reading for yellow varied between 83° 56′ and 84° 37′. As the green and red lights were not so brilliant it was harder to bring the hyperbolæ on the cross-hairs of the instrument and the values can not be regarded as very accurate; they serve, however, to show the small dispersion of the optical axes, which is $\rho < v$. Small cleavage chips of the mineral show under the polarizing microscope with crossed nicols very little change in color on revolving the stage, but in convergent polarized light an optical axis is seen almost in the center of the field. The optical axes are therefore almost at right angles to the prismatic faces. Indices of refraction were not determined. The hardness of the mineral is about 2·5. The crystals readily scratch gypsum but cannot be made to scratch calcite. The specific gravity was determined by just floating the crystals in the Thoulet solution and found to be 1·83. The solution had a slight solvent action on the mineral, carbon dioxide being liberated, bubbles of which attached themselves to the crystals and buoyed them up. The specific gravity had to be taken therefore very carefully after washing the crystals and taking the observation before any appreciable chemical action had set in. A specific gravity determination made in alcohol gave 1·852, agreeing closely with the above.

For the chemical analysis only the best crystals were used, which after drying for three days over sulphuric acid lost only 0·10 per cent and showed a few opaque spots resulting probably from a slight contamination of lansfordite. The analysis yielded:

	I.	II.	III.	IV.	Average.	Ratio.	
CO_2		30·18		30·25	30·22	·687	1·
H_2O and CO_2	70·56		70·52				
MgO	29·44	29·24	29·18	29·04	29·22	·731	1·06
H_2O					40·32	2·240	3·26
					99·76		

The ratio of $CO_2 : MgO : H_2O$ is about 1 : 1 : 3, agreeing with the formula $MgCO_3 . 3H_2O$. The calculated percentage composition of a mineral with the above formula being:

CO_2	31·38
MgO	28·99
H_2O	39·13

which also agrees closely with chemical analysis.

Artificial nesquehonite.

A salt of the composition $MgCO_3 . 3H_2O$ is most readily obtained by dissolving magnesium carbonate in water containing carbon dioxide and allowing the solution to stand till it deposits crystals. The preparation of this salt we find mentioned in Klaproth's Chemisches Wörterbuch, edition of 1808, where it is stated that it crystallizes in transparent six sided prisms, terminated by a six-sided basal plane, but the water of crystallization is not mentioned. In Berzelius' Chemie, edition of 1835, the same method of preparation and description of the salt are given with mention of the three molecules of water of crystallization. In 1855, Marignac* published his results of the crystallographic measurement of the crystals, which he describes as brilliant but deeply striated orthorhombic prisms. He observed *c*, 001, *O*; *b*, 010, *i-ĭ*; *m*, 110, *I* and *d*, 011, 1-ĭ, the same forms which occur on the natural mineral. His measurements are:

	Marignac.	Nesquehonite, Penfield.
$m \wedge m$ 110 $\wedge 1\bar{1}0$	64°	65° 36′
$d \wedge d$ 011 $\wedge 0\bar{1}1$	47	49 6

We prepared a quantity of the salt, which crystallized in radiating tufts of prismatic crystals. Individual crystals were scarcely over 0·2^{mm} in diameter and about 2·0^{mm} long. Most of them were terminated by a simple basal plane and showed either a rhombic or hexagonal cross section according as *b*, 010, was wanting or present. Sixteen of these little crystals were measured on the reflecting goniometer in hopes of finding one which would give sharp reflections of the signal, but owing to the small size of the crystals and some physical unevenness of the faces the angles admitted of only approximate measurement and showed considerable variation. The prismatic angle varied from 64° 30′ to 68° 45′, most of the

* Mém. de la Soc. de Phys. and D'Hist. Nat. de Genève, xiv, p. 252.

crystals, and among these the best, giving an angle of nearly 66°, which is about that obtained from the natural mineral. One of the largest of the crystals served as a prism for measuring the indices of refraction. The prismatic angle measured 68° 20′; the minimum deviation for yellow light, soda flame, was found to be 46° 40′ for rays vibrating parallel to the vertical axis of the prism and 49° 40′ for rays vibrating parallel to the macro axis. Two of the indices of refraction are therefore $\beta=1{\cdot}501$ and $\gamma=1{\cdot}526$. The relation of the axes of elasticity to the crystallographic is therefore the following $\overline{a}=a$, $b=c$ and $c=b$. The brachy-axis being the acute bisectrix the double refraction is negative the same as in the natural mineral. As a further proof of the identity of the natural and artificial salts we find that the two show exactly the same behavior in convergent polarized light; one of the little crystals lying on a prismatic face shows in convergent polarized light one optical axis almost in the center of the field, the base as the plane of the optical axes and a strong double refraction. Making use of $\beta=1{\cdot}501$ for yellow in the determination of the divergence of the optical axes in the natural mineral $2E=84°\ 15'$, we find $2V=53°\ 5'$, from which we see that the optical axes vary only about 6° from a normal to the prismatic faces. Also having $2V=53°\ 5'$, $\beta=1{\cdot}501$ and $\gamma=1{\cdot}526$ we can calculate $\alpha=1{\cdot}495$.

Owing to the ease with which this simple carbonate of magnesia can be produced artificially in crystals and its stability, for the crystals do not lose water in the warm, dry air of a laboratory nor in a desiccator over sulphuric acid, it would seem to be a very natural compound to find in nature; it is, however, probable that its solubility, especially in water containing carbon dioxide, would account for its absence in localities which would seem favorable for its formation. The hydrated carbonates of magnesia which up to this time have been found in nature are basic and are:

Hydromagnesite	$3MgCO_3,\ Mg(OH)_2,\ 3H_2O$
Lansfordite	$3MgCO_3\ Mg(OH)_2\ 21H_2O$
Hydrogiobertite	$MgCO_3\ Mg(OH)_2\ 2HO_2$ or $Mg_2CO_4.3H_2O$

The last of these is a mineral which has recently been described by E. Scacchi* as occurring in dense spherulitic masses from 2 to 15^{mm} diameter in a lava at Pollina, Sicily. The formula written $Mg_2CO_4 3H_2O$ reminds one very much of our mineral but requires 44·94 per cent MgO, while the nesquehonite requires only 28·99 per cent.

* Rendi. della R. Acad. delle. Sci. di Napoli 12, Dic. 1885.

Pseudomorphs of nesquehonite after lansfordite.

Mention has already been made in the first part of this paper and in the original article by Dr. Genth* of the occurrence of lansfordite. On the specimens which were first collected no nesquehonite prisms were visible, but by the time when the second lot was obtained owing to some process a decomposition and recrystallization of the material of the lansfordite had gone on in the mine, resulting in the formation of the nesquehonite crystals. This recrystallization, resulting in the formation of rather large crystals, had in all cases commenced at the base of the stalactites and incrustations, leaving the ends of the stalactites still unaltered lansfordite and no real pseudomorphs were found, while the white cryptocrystalline mineral which was formed afterwards from the lansfordite during a period of warm summer temperature has resulted in the production of perfect pseudomorphs, leaving not only the original stalactite form but also the flat crystal faces at the ends well preserved, the stalactites looking like bits of crayon upon the ends of which flat faces had been worn by writing on a black-board. When the specimens were first sent to New Haven in the spring of 1889, there were among them only two specimens, one a small fragment the other a small stalactite, which still showed the paraffine luster, but when the crystallographic work was commenced in the fall of 1889, these two specimens had also lost their luster and become almost completely changed into the opaque white material. The altered stalactites show on a fractured surface with a strong lens a fine fibrous structure, the fibers either radiating or inter-woven like felt and giving a sort of "schimmer" when held in a strong light. In places it appears dense like chalk or crypto-crystalline. When carefully crushed and mounted in Canada balsam it shows with the microscope throughout a fine fibrous structure, the larger fibers, which happen to lie on a prismatic or cleavage face giving the same optical properties as nesquehonite. This fibrous material has proved on examination to be like nesquehonite in its chemical composition, an analysis giving:

		Ratio.			Calculated. Nesquehonite.	Lansfordite.
CO_2	28·85	0·656	0·93	1·	31·88	19·19
MgO	28·23	0·706	1·00	1·	28·99	23·25
H_2O	42·92	2·384	3·37	3·	39·13	57·56
	100·00					

The analysis and ratio indicate the composition $MgCO_3 \cdot 3H_2O$, the variation from the theoretical being too little CO_2 and too much H_2O resulting probably from a slight admixture of

* Loc. cit.

unaltered lansfordite. For more ready comparison we have given the calculated percentage composition of both nesquehonite and lansfordite.

From the above observations we conclude that the lansfordite is very unstable, losing its water and changing into nesquehonite at a very moderate temperature. Under ordinary conditions this change goes on so rapidly that only microscopic crystals are developed and perfect pseudomorphs are formed. In the mine, where we should expect the temperature conditions to be uniform, the change undoubtedly went on slowly and quite large crystals were formed. We should not expect the summer temperature in the mine to be as high as out of doors, and what agency had been at work in bringing about the change other than rise of temperature we do not know. It is probable that the lansfordite was discovered very soon after its formation and we feel that we were very fortunate in obtaining it before its conversion into nesquehonite.

Crystallization of lansfordite.

Lansfordite is at present only known in pseudomorph crystals; these are, however, so unlike anything which we have ever seen before that they have been subjected to very careful crystallographic study. They are exceedingly interesting as they show a curious combination of stalactitic and crystal growth. The stalactites are mostly round and tapering like ordinary stalactites, but on and near the ends they have perfectly flat crystal faces; these have rounded contours where they join the curved surface of the stalactites and frequently two crystal faces, instead of coming together forming a straight edge, are separated by a curved stalactitic surface. On looking over the material, at first all hopes of measuring the crystals on a reflecting goniometer by direct reflection of light was given up as the faces seemed too dull for that purpose. Two of the crystals were therefore laboriously measured by placing a little Canada balsam on the faces and pressing small bits of thin cover glass upon them before placing them on the goniometer. This method gave rather unsatisfactory results, especially for the smaller faces and was soon abandoned, as it was found that in cleaning up the crystals with alcohol and wiping them with cloth a slight polish was developed on the faces, causing them to give a slight reflection of light, sufficient for an approximate measurement of the angles by using a strong illumination and the low ocular (δ of Websky) on the Fuess reflecting goniometer. It was also soon found that most of the crystal faces were so smooth and perfect that without any polishing they gave, with strong illumination and a low ocular, a fair reflection of light. Altogether there were sent to New Haven

thirteen crystals or parts of stalactites which seemed suitable for measurement and these have been conveniently designated in the following pages by numbers.

No. 1. The best crystal of all was a small one about 5^{mm} in its greatest diameter, which was attached to one of the larger stalactites and readily separated from it leaving an angular cavity, marked with regular lines which are so often seen in breaking apart two crystals which have accidentally grown together. This small crystal gave distinct reflections of the signal and values which can probably be relied on within half a degree. The crystal is triclinic and is shown in fig. 2. The observed forms have been taken as follows: *c*, 001, *O*; *b*, 010, i-$\breve{\imath}$; M, $1\bar{1}0$, *I*; *m*, 110, *I'*; *d*, 021, 2-$\breve{\imath}'$; *p*, $1\bar{1}1$, -1 and *r*, $1\bar{3}2$, $-\frac{3}{2}$-$\breve{3}$. The following measurements were chosen as fundamental.

$c \wedge b$, $001 \wedge 010 = 84°\ 6'$	$b \wedge$ M, $010 \wedge \bar{1}10 = 64°\ 13'$
$c \wedge$ M, $001 \wedge \bar{1}10 = 96\ 35$	$m \wedge$ M, $\bar{1}10 \wedge \bar{1}10 = 56\ 57$
$b \wedge d$, $010 \wedge 021 = 39°\ 16'$	

from which the following relations are calculated.

$a = 95°\ 22'$
$\beta = 100\ 15$ $\qquad \breve{a} : \breve{b} : \dot{c} = 0{\cdot}5493 : 1 : 0{\cdot}5655$
$\gamma = 92\ 28$

In addition to the fundamental measurements given above the following were made for the identification of the pyramids.

		Calculated.
$m \wedge p$, $110 \wedge 1\bar{1}1$	$= 59°\ 36'$	$58°\ 56'$
$p \wedge r$, $1\bar{1}1 \wedge 1\bar{3}2$	$= 21\ 17$	$21\ 41$
$c \wedge p$, $001 \wedge 1\bar{1}1$	$= 44\ 1$	$44\ 59$

This crystal, which was attached at its lower end, in reality showed none of the M face and only a little of *m* in front, but on top and behind it was quite perfect except for a slight rounding off of the vertical edges between 010, $\bar{1}10$ and $\bar{1}\bar{1}0$ by a stalactitic surface.

The position which we have adopted for our crystal is probably as good as any which could have been chosen for showing the relation of the faces. On the thirteen stalactites which we have examined twenty-four separate forms have been identified whose relations and zones can be well understood from the spherical projection, fig. 3, and which are distributed as follows:

Pinacoids.	Prisms.	Domes.
c, 001, *O*	*m*, 110, *I'*	*d*, 021, 2-$\breve{\imath}'$
b, 010, i-$\breve{\imath}$	M, $1\bar{1}0$, *I*	*e*, $0\bar{2}1$, 2-$\breve{\imath}$
	h, 150, i-$\breve{5}'$	*f*, $\bar{2}01$, 2-$\breve{\imath}$
	k, $3\bar{1}0$, i-$\breve{3}$	
	l, $1\bar{7}0$, i-$\breve{7}$	

Pyramids in the four upper octants.

Front right.	Front left.	Back right.	Back left.
P, 111, − 1′	p, $1\bar{1}1$, − 1	y, $\bar{1}11$, 1′	n, $\bar{1}\bar{1}1$, 1
	q, $3\bar{1}2$, $-\frac{3}{2}$-$\bar{3}$	x, $\bar{1}32$, $\frac{3}{2}$-$\breve{3}'$	o, $\bar{1}\bar{1}2$, $\frac{1}{2}$
	r, $1\bar{3}2$, $-\frac{3}{2}\bar{3}$	z, $\bar{3}12$, $\frac{3}{2}$-$\bar{3}'$	ρ, $\bar{1}31$, 3-$\bar{3}$
	s, $1\bar{7}2$, $-\frac{7}{2}$-$\breve{7}$	w, $\bar{5}\,15\,1$, 15-$\breve{3}'$	π, $\bar{1}52$, $\frac{5}{2}$-$\bar{5}$
	τ, $12\,\bar{1}\bar{2}\,21$, $-\frac{12}{11}$-$\breve{\frac{6}{5}}$		

As the thirteen crystals which were sent to New Haven offered a great diversity of habit it was found necessary to study and discuss each one separately. In the figures which have been drawn, a mere outline of the stalactite has been given with no attempt at artistic shading. In all of the drawings the flat crystal faces have been lettered and can thus be distinguished from the rounded stalactitic surfaces which are unlettered and show throughout curved contours. After establishing the triclinic character and axial relation of the mineral from the fundamental measurements considerable difficulty was found in orientating some of the more complicated crystals; this was rendered all the more difficult as none of the crystals gave very exact measurements and cleavage, luster or any decided crystalline habit failed entirely, but after becoming familiar with some of the principal zones in a few of the more complicated crystals this difficulty disappeared. It should also be stated here that during the investigation no uncertain reflections were seen which were neglected, all of the reflections were recorded and in every case they could be referred to faces having rational indices and in only two cases τ and w were these indices unusual numbers: The zonal relations were throughout very satisfactory.

No. 2. This is a very simple stalactite about 22^{mm} long and 9 in diameter, terminated at the end by only two crystal faces and with one large prominent face on the side, fig. 4. Reflections were obtained from the faces by sticking glass plates to them and the measured angles, which are not very exact, indicate that the faces are probably c 001, p $1\bar{1}1$ and m 110. The angles are as follows:

		Calculated.
$c \wedge p$,	$001 \wedge 1\bar{1}1 = 42° 30'$	44° 59′
$c \wedge m$,	$001 \wedge 110 = 77\ 40$	78 12
$p \wedge m$,	$1\bar{1}1 \wedge 110 = 61$	58 56

No. 3 is a stalactite, which is very similar to the previous one, and is terminated by only two faces which are probably c 001 and d 021, giving the measurement $c \wedge d = 44° 56'$ calculated 44° 50′.

No. 4 is a stalactite about 15^{mm} long and 8 in diameter attached at the base to a mass of radiating prismatic crystals of nesquehonite. At the end it is terminated mostly by a

brachypinacoid b $0\bar{1}0$ and shows in addition M $1\bar{1}0$, m $\bar{1}\bar{1}0$, p $1\bar{1}1$ and c 001. A measurement of the two zones M, b, m and M, p, c was sufficient for a determination of the faces, which when drawn in proper position represent the stalactite as laying on its side. The crystal is represented in fig. 5, where b and m being to the left and behind are not shown. The measured angles are:

		Calculated.				Calculated.	
M ∧ b,	$1\bar{1}0 \wedge 0\bar{1}0$	65° 30′	64° 13′	M ∧ p,	$1\bar{1}0 \wedge 1\bar{1}1$	39° 25′	38° 26′
b ∧ m,	$0\bar{1}0 \wedge \bar{1}\bar{1}0$	57 9	58 50	p ∧ c,	$1\bar{1}1 \wedge 001$	44 30	44 59
c ∧ b,	$001 \wedge 0\bar{1}0$	96 30	95 54				

The b face not being very perfect accounts for a rather large variation from the theoretical for the first three angles. It was from this crystal that the smaller one was taken, No. 1, which was used for obtaining the fundamental measurements. It was attached at the end of the stalactite, separated readily from it and had no definite crystallographic relation to the larger crystal.

No. 5, is a short stalactite about 10^{mm} long and broad attached at the base to a mass of nesquehonite crystals. Like the previous stalactite the prominent face at the end is a brachypinacoid b $0\bar{1}0$, with which the following forms are associated. M, $1\bar{1}0$; l, $1\bar{7}0$; h, $\bar{1}\bar{5}0$; c, 001; e, $0\bar{2}1$; p, $1\bar{1}1$; r, $1\bar{3}2$; s, $1\bar{7}2$; and o, $\bar{1}\bar{1}2$, which were identified by measurements made in the following prominent zones M, l, b and h; M, p and c; p, r and e; b, s and r; s, e and o and b, e and c. As the faces intersect the negative end of the b axis the figure, No. 6, has been drawn representing the crystal as turned about the vertical axis so that the negative end of $\bar{b}$ is in front and the positive end of $\breve{a}$ to the right. We are thus looking as it were directly at the end of the stalactite. The face b is in two levels separated by a narrow prismatic face h $\bar{1}\bar{5}0$. The angular marking at the lower left hand corner of the drawing represents where a small crystal was detached. The important measurements in the zones mentioned above are as follows.

		Calculated.				Calculated.	
M ∧ l,	$1\bar{1}0 \wedge 1\bar{7}0$	49° 15′	49° 16′	b ∧ s,	$0\bar{1}0 \wedge 1\bar{7}2$	33° 34′	33° 24′
M ∧ b,	$1\bar{1}0 \wedge 0\bar{1}1$	63 30	64 13	s ∧ r,	$1\bar{7}2 \wedge 1\bar{3}2$	26 36	26 14
l ∧ h,	$1\bar{7}0 \wedge 1\bar{5}0$	33 30	34 16	s ∧ e,	$1\bar{7}2 \wedge 0\bar{2}1$	18 25	19 2
M ∧ p,	$1\bar{1}0 \wedge 1\bar{1}1$	39	38 26	e ∧ o,	$0\bar{2}1 \wedge \bar{1}\bar{1}2$	42 26	42 14
p ∧ c,	$1\bar{1}1 \wedge 001$	44 5	44 59	b ∧ e,	$0\bar{1}0 \wedge 0\bar{2}1$	45	44 32
p ∧ r,	$1\bar{1}0 \wedge 1\bar{3}2$	21 30	21 41	e ∧ c,	$0\bar{2}1 \wedge 001$	51 30	51 22
r ∧ e,	$1\bar{3}2 \wedge 0\bar{2}1$	23 52	24 36				

On this crystal we find for the first and only time l and s. l gives a faint but distinct reflection and gives a measurement on M very close to the calculated; s is very surely determined both by its zones and the angles which do not vary much from the calculated. The prism h $\bar{1}\bar{5}0$ gave a poor reflection, as b,

$0\bar{1}0$ also reflected poorly the angle of h on l was taken for the identification of h. The angle varies 46′ from the theoretical but considering the poor reflection of the signal and that this same form was identified on two other crystals we feel very sure that we have given to h the proper indices. A second faint reflection was obtained from a face 3° from h and corresponding nearly to $\bar{1}60$ but the measurement is not very exact and the form does not occur on any other crystals, so that we do not feel warranted in numbering this among our list of planes.

No. 6 is like an incrustation or very short stalactite covering the ends of a cluster of radiating nesquehonite crystals. The incrustation is terminated by a very prominent brachypinacoid b, 010, measuring 9 by 7^{mm} with which the following forms are associated, m, 110; M, $\bar{1}10$; h, 150; d, 021; e, $02\bar{1}$; c, 001; p, $1\bar{1}1$ and $\bar{1}1\bar{1}$ and r, $\bar{1}3\bar{2}$; figure 7 represents the arrangement of the faces on this crystal. The large b face is in three levels separated by narrow m, p and d faces. At the back of the crystal we find a zone of three small faces p, r and e indicated by dotted lines, as e is reduced almost to a line, in one projection it does not show on any of the figures except the basal projections. As we usually have on these stalactites only the faces corresponding to one end or corner of a crystal it is seldom that we have two parallel faces as the pyramid p $1\bar{1}1$ and $\bar{1}1\bar{1}$ in this example. In the following table will be found the angles which were measured in the prominent zones for the identification of the faces.

		Calculated.				Calculated.
$b \wedge$ M, $010 \wedge \bar{1}10$	64°	64° 13′	$p \wedge c$, $1\bar{1}1 \wedge 001$	44° 15′	44° 59′
$b \wedge m$, $010 \wedge 110$	59 30′	58 50	M $\wedge p$, $\bar{1}10 \wedge 1\bar{1}\bar{1}$	39 4	38 26
$m \wedge h$, $110 \wedge 150$	38 15	39 31	$p \wedge r$, $1\bar{1}\bar{1} \wedge \bar{1}3\bar{2}$	21 43	21 41
$b \wedge d$, $010 \wedge 021$	39 30	39 16	$r \wedge e$, $\bar{1}32 \wedge 02\bar{1}$	24	24 35
$d \wedge c$, $021 \wedge 001$	44 30	44 50			

No. 7 is a small fragment of a stalactite about 11^{mm} in its greatest diameter. The faces which are present are represented in about their natural development in fig. 8. Crystal faces are present only in the front, lower and right hand part of the crystal. The following forms were present: c, $00\bar{1}$; b, 010; m, 110; k, $3\bar{1}0$; M, $1\bar{1}0$ and $\bar{1}10$; g, $3\bar{1}2$; z, $\bar{1}23$; y, $1\bar{1}\bar{1}$; x, $1\bar{3}\bar{2}$; n, $11\bar{1}$; o, $11\bar{2}$, e, $02\bar{1}$ and p, $\bar{1}1\bar{1}$. The prominent zones which were measured for the identified of the faces are as follows: b, m, k and M; m, z, y and x; m, n and o; z, k and M, q and p and c. The measured angles are as follows:

		Calculated.				Calculated.
$b \wedge m$, $010 \wedge 110$	64°	64° 13′	$m \wedge n$, $110 \wedge 11\bar{1}$	45° 27′	44° 37′
$m \wedge k$, $110 \wedge 3\bar{1}0$	37 32′	38 2	$m \wedge o$, $110 \wedge 11\bar{2}$	68 45	68 5
$k \wedge$ M, $3\bar{1}0 \wedge 1\bar{1}0$	19 17	18 55	$k \wedge z$, $3\bar{1}0 \wedge 3\bar{1}2$	37	35 29
$m \wedge z$, $110 \wedge 3\bar{1}\bar{2}$	55 40	53 22	$k \wedge q$, $3\bar{1}0 \wedge 3\bar{1}\bar{2}$	30 23	29 59
$z \wedge y$, $3\bar{1}\bar{2} \wedge 1\bar{1}\bar{1}$	19 45	20 8	M $\wedge p$, $\bar{1}10 \wedge \bar{1}1\bar{1}$	39 15	38 26
$y \wedge x$, $1\bar{1}\bar{1} \wedge 1\bar{3}\bar{2}$	24	25 6	$p \wedge c$, $\bar{1}1\bar{1} \wedge 00\bar{1}$	44 37	44 59

The zones and the approximate measurement of the angles fully determine the forms on this crystal. The dome *e*, which is relatively quite a large face, is reduced almost to a line in our projection.

No. 8 is one of the most perfect of the stalactites; it is short, 10mm long and 6mm in diameter. At the base the white material of the altered lansfordite spreads out very much and covers a group of nesquehonite prisms which are attached to a piece of carbonaceous shale. The planes which are present are very symmetrically grouped, reminding one of a monoclinic crystal, and are as follows: *b*, 010; *c*, 001; M 1$\bar{1}$0 and $\bar{1}$10; *d*, 021; *e*, 02$\bar{1}$; *x*, $\bar{1}$23; *y*, $\bar{1}$11; *p*, 1$\bar{1}$1 and *r*, 1.2. The arrangement of the faces in about their natural development is shown in fig. 9, while fig. 10, which is a projection on a plane at right angles to the vertical axis, will give a somewhat better idea of the symmetrical arrangement of the faces. The large basal plane *c* is in two levels, and to the left there is a cleft in the stalactite which is also bounded by crystal faces, not shown in the drawing. The faces of the crystal were quite devoid of luster before rubbing and polishing with a soft cloth, by which treatment the edges were somewhat rounded and the angles of the faces slightly changed; however, the faces can be fully determined by the zones and the approximate measurements. The angles measured in the prominent zones are as follows:

			Calculated.				Calculated.
b ∧ M, 010 ∧ $\bar{1}$10	64°		64° 13′	*d* ∧ *x*, 021 ∧ $\bar{1}$32	21°	10′	20° 20′
b ∧ *d*, 010 ∧ 021	39	30	39 16	*x* ∧ *y*, $\bar{1}$32 ∧ $\bar{1}$11	24	40	22 50
d ∧ *c*, 021 ∧ 001	45	10	44 50	*r* ∧ *c*. 1$\bar{3}$2 ∧ 001	41	25	43 24
c ∧ *e*, 001 ∧ 02$\bar{1}$	49		51 22	*c* ∧ *x*, 001 ∧ $\bar{1}$32	44	50	43 52
p ∧ *r*, 1$\bar{1}$1 ∧ 1$\bar{3}$2	19	54	21 41	M ∧ *y*, 110 ∧ $\bar{1}$11	43	30	44 10
r ∧ *e*, 1$\bar{3}$2 ∧ 02$\bar{1}$	25	24	24 36	*y* ∧ *c*. $\bar{1}$11 ∧ 001	53	30	52 25

Nos. 9 and 10 are two crystals which had grown together into a single stalactite about 25mm long by 8mm diameter, and readily separated lengthwise with the stalactite. At the junction of the two crystals at the lower end there was a deep reentrant angle, reminding one of a twin crystal but there seemed to be no crystallographic relation between the two halves, and we probably have to do simply with the growth of two crystals into one stalactite. This much must be said, however, that the axis of the stalactite corresponds closely to the vertical axis of the crystals, and the faces on the two crystals for the most part intersect the negative end of the vertical axis. One of these crystals is represented in fig 11. The rounded surface of the stalactite is behind, while in front there is an angular marking indicating the surface by which the two crystals were united and at the lower end a group of crystal faces, which are as follows: *b*, 010; *c*, 001; *h*, 150; *m*, 110; *d*, 021; *e*, 02$\bar{1}$; *r*, $\bar{1}$2$\bar{2}$ and *p*, $\bar{1}$1$\bar{1}$. The angles were measured in the

following zones: b, h and m; p, r, e and m and d, b, e and c; and are as follows:

		Calculated.				Calculated.
$b \wedge m$, 010 ∧ 110	56° 47′	58° 50′	$d \wedge b$, 021 ∧ 010	38° 55′	39° 16′
$h \wedge m$, 150 ∧ 110	39 11	39 31	$b \wedge e$, 010 ∧ 02$\bar{1}$	45	44 32
$p \wedge r$, 1$\bar{1}$1 ∧ $\bar{1}$3$\bar{2}$	21 31	21 41	$e \wedge c$, 02$\bar{1}$ ∧ 00$\bar{1}$	50 50	51 22
$r \wedge e$, $\bar{1}$3$\bar{2}$ ∧ 02$\bar{1}$	24 9	24 36			

The other half of this stalactite is shown in fig. 12, where the rounded stalactitic surface is in front, while the small group of crystal faces, which are mostly in the back, are indicated by dotted lines. The forms which were identified are as follows: M, 1$\bar{1}$0; m, 110; c, 00$\bar{1}$; b, 0$\bar{1}$0; d, 0$\bar{2}\bar{1}$; e, 02$\bar{1}$; p, $\bar{1}$1$\bar{1}$; r, $\bar{1}$3$\bar{2}$ and x, 1$\bar{3}\bar{2}$, and were measured in the following zones: b, M and m, p, r and e; b, d, c and e; and r, c and x, the angles being as follows:

		Calculated.				Calculated.
$b \wedge$ M, 0$\bar{1}$0 ∧ 1$\bar{1}$0	64° 10′	64° 13′	$b \wedge d$, 0$\bar{1}$0 ∧ 0$\bar{2}\bar{1}$	39° 5′	39° 16′
M ∧ m, 1$\bar{1}$0 ∧ 110	57 15	56 57	$d \wedge c$, 0$\bar{2}\bar{1}$ ∧ 00$\bar{1}$	44 50	44 50
$p \wedge r$, 1$\bar{1}$1 ∧ $\bar{1}$3$\bar{2}$	21 30	21 41	$c \wedge e$, 00$\bar{1}$ ∧ 02$\bar{1}$	51 5	51 22
$r \wedge e$, $\bar{1}$3$\bar{2}$ ∧ 02$\bar{1}$	24 25	24 36	$r \wedge c$, $\bar{1}$2$\bar{2}$ ∧ 00$\bar{1}$	44 5	43 24
			$c \wedge x$, 00$\bar{1}$ ∧ 1$\bar{1}\bar{2}$	42	43 52

No. 11 is a small stalactite 18^{mm} long by 7^{mm} diameter, which when it was first sent to New Haven in the spring of 1889, still showed the paraffine luster of the unaltered lansfordite; when it was measured in the following fall it was only partially altered to nesquehonite, but had become almost completely changed by the first of December. The faces did not give good reflections of light, but as the angles which were measured on this partially altered crystal do not vary widely from the calculated, which were obtained from the measurement of a completely altered crystal, we conclude that in the change of composition the angles of the lansfordite have not been very materially changed. The faces which were identified are as follows: b, 010; c, 10$\bar{1}$; m, 100; M, 1$\bar{1}$0; p, $\bar{1}$1$\bar{1}$; d, 0$^{2}\bar{1}$; and P, $\bar{1}\bar{1}$1, x, 1$\bar{3}\bar{2}$, and are arranged as shown in fig. 13. The angles were measured in the following zones: b, m and M; m, c and P; and m, x and d, and are as follows:

		Calculated.			Calculated.
$b \wedge m$, 010 ∧ 110	59° 15′	58° 50′	$m \wedge c$, 110 ∧ 00$\bar{1}$	103° 30′	101° 48′
$m \wedge$ M, 110 ∧ 1$\bar{1}$0	58	56 57	$c \wedge$ P, 00$\bar{1}$ ∧ $\bar{1}\bar{1}$	44 30	43 15
$d \wedge x$, 0$\bar{2}\bar{1}$ ∧ 1$\bar{3}\bar{2}$	19	20 20	$c \wedge p$, 00$\bar{1}$ ∧ 1$\bar{1}$	44 30	44 59

This is the only crystal on which the pyramid P, 111 was identified, and here it occurs only as a very small face which is not represented in the drawing. It is interesting to find on the mineral all of the four possible faces making up the triclinic unit pyramid. On this crystal we notice that the decomposition or change from lansfordite to nesquehonite proceeds along certain planes which are parallel to the base. It is probable that these planes indicate the direction of cleavage of the

lansfordite. On breaking across the stalactite near the base where it seemed wholly altered to nesquehonite, it parted with nearly a plane surface parallel to *c*, 001.

No. 12 is a small end of a stalactite about 8mm in diameter. Like the previous one it showed at the time the measurements were made a little of the paraffine luster of the unaltered lansfordite. The crystal is highly modified and shows the following forms: *b*, 010; *c*, 001; *d*, 021; *e*, $0\bar{2}1$; M, $\bar{1}10$; *x*, $\bar{1}32$; *y*, $\bar{1}11$; *n*, $\bar{1}\bar{1}1$; *o*, $\bar{1}\bar{1}2$; *q*, $3\bar{1}2$; *p*, $1\bar{1}1$; *r*, $1\bar{3}2$; *π*, $1\bar{5}\bar{2}$; *ρ*, $\bar{1}\bar{3}1$ and *w*, $\bar{5}151$. These are represented in about their natural size in fig. 14, which is a projection upon a plane at right angles to the vertical axis and which in this case is better than an ordinary projection for showing the relation of the faces. The prominent zones which were measured are: *b*, *d*, *c* and *e*; *d*, *x* and *y*; *c*, *o* and *n*; *c*, *y* and M; *q*, *p*, *r*, *e*, *π* and *ρ*, and *r*, *c*, *x* and *w*, the angles being:

		Calculated.	
b ∧ *d*, 010 ∧ 021 =	39° 25′	39°	16′
d ∧ *c*, 021 ∧ 001 =	44 57	44	50
c ∧ *e*, 001 ∧ $0\bar{2}1$ =	53 35	51	22
d ∧ *x*, 021 ∧ $\bar{1}32$ =	35 20	20	20
x ∧ *y*, $\bar{1}32$ ∧ $\bar{1}11$ =	24 15	22	50
c ∧ *o*, 001 ∧ $\bar{1}\bar{1}2$ =	33 30	33	43
c ∧ *n*, 001 ∧ $\bar{1}\bar{1}1$ =	56 38	57	11
c ∧ *y*, 001 ∧ $\bar{1}11$ =	52 40	52	25
y ∧ M, $\bar{1}11$ ∧ $\bar{1}10$ =	44 40	44	10

		Calculated.	
q ∧ *p*, $3\bar{1}2$ ∧ $\bar{1}11$ =	15° 20′	15°	3′
p ∧ *r*, $1\bar{1}1$ ∧ $1\bar{3}2$ =	21 38	21	41
e ∧ *r*, $0\bar{2}1$ ∧ $1\bar{3}2$ =	23 51	24	36
e ∧ *π*, $0\bar{2}1$ ∧ $1\bar{5}\bar{2}$ =	18 21	20	2
e ∧ *ρ*, $0\bar{2}1$ ∧ $\bar{1}\bar{3}1$ =	32 36	33	42
π ∧ *ρ*, $1\bar{5}\bar{2}$ ∧ $\bar{1}\bar{3}1$ =	14 15	13	34
r ∧ *c*, $1\bar{3}2$ ∧ 001 =	45 44	43	25
c ∧ *x*, 001 ∧ $\bar{1}32$ =	44	43	52
x ∧ *w*, $\bar{1}32$ ∧ $\bar{5}151$ =	35 16	35	22

In this crystal we notice for the first time two new pyramids *π* and *ρ* in the zone *p*, *r*, *e* which has been so prominent in most all of the crystals, we also notice for the first and only time the very steep pyramid *w* in the zone *r*, *c*, *x*.

No. 13 is a fragment about 19mm by 11mm wide, with some rounded surfaces, which was broken from a much larger piece of incrustation; except for the rounded surfaces the incrustation did not have anything of a stalactitic habit. The fragment which was measured separated readily from the rest of the incrustation, leaving angular markings which indicate the juncture of independent and distinct crystals. It was more highly modified than the remaining parts of the incrustation and showed the following forms, *b*, both 010 and $0\bar{1}0$; *c*, 001; M, $\bar{1}10$; *k*, $\bar{5}10$; *m*, $\bar{1}\bar{1}0$; *d*, 021; *e*, $0\bar{2}1$; *o*, $\bar{1}\bar{1}2$; *n*, $\bar{1}\bar{1}1$; *x*, $\bar{1}32$; *y*, $\bar{1}11$; *z*, $\bar{5}12$; *f*, $\bar{2}01$; *p*, $1\bar{1}1$; *τ*, $10\ \bar{1}2\ 11$, *r*, $1\bar{3}2$, *π*$1\bar{5}2$ and *ρ*, $\bar{1}\bar{3}1$. The arrangement of the faces is shown in about their natural size and developement in fig. 15, which is a projection upon a plane at right angles to the vertical axis. The prominent zones which were measured are *b*, M, *k* and *m*; *c*, *o* and *n*; *d*, *x*, *y*, *z*, *f* and *m*; *b*, *d*, *c*, *e* and *b′*; and *p*, *τ*, *r*, *e*, *π* and *ρ* the angles being—

		Calculated.	
$b \wedge$ M, 010 $\wedge \bar{1}10$	63°	50′	64° 13′
M $\wedge$ *k*, $\bar{1}10 \wedge \bar{3}10$	20	20	18 55
m $\wedge$ M, $\bar{1}10 \wedge 1\bar{1}0$	56	30	56 57
d $\wedge$ *x*, 021 $\wedge$ .32	21	40	20 20
x $\wedge$ *y*, $\bar{1}32 \wedge \bar{1}11$	24		22 50
y $\wedge$ *z*, $\bar{1}11 \wedge \bar{3}12$	20	0	20 8
y $\wedge$ *f*, $\bar{1}11 \wedge \bar{2}01$	33	10	32 59
f $\wedge$ *m*, $\bar{2}01 \wedge \bar{1}0$	41	15	41 31
c $\wedge$ *o*, 001 $\wedge \bar{1}\bar{1}2$	32		33 43
c $\wedge$ *n*, 001 $\wedge \bar{1}\bar{1}1$	56	45	57 11

		Calculated.	
$b \wedge d$, 010 $\wedge$ 021	39°	30′	39° 16′
$d \wedge c$, 021 $\wedge$ 001	44	45	44 50
$c \wedge e$, 001 $\wedge 0\bar{2}1$	51	25	51 22
$e \wedge b'$, $0\bar{2}1 \wedge 0\bar{1}0$	44	25	44 32
$p \wedge e$, $1\bar{1}1 \wedge 0\bar{2}1$	46		46 16
$\tau \wedge e$, $101\bar{2}11 \wedge 0\bar{2}1$	43		42 49
$r \wedge e$, $1\bar{3}2 \wedge 0\bar{2}1$	24	15	24 36
$e \wedge \pi$, $0\bar{2}1 \wedge \bar{1}52$	20		20 8
$e \wedge \rho$, $0\bar{2}1 \wedge \bar{1}31$	32	30	33 42

At one edge of our crystal, near the top and middle in fig. 15, we notice a little indentation where three small faces *f*, *z* and *y* form zone, a few millimeters to the right we again find *z* and *y* but separated from the former by a curved stalactitic surface and also by the pyramids *n* and *o*. The small face *f* is very perfect and is here observed for the first time. It has a very simple symbol $\bar{2}01$, 2-$\bar{2}$ and is readily determined by its angles with the faces *m* and *y* in the zone. Another feature of this crystal is the highly developed zone *p*, *r*, *e*, where we notice for a second time the pyramids π and ρ. The pyramid *p* is present only as a very small face but gave a distinct reflection, the pyramid τ however, which is only a few degrees removed it is a face of considerable size. The symbol 10 $\bar{1}\bar{2}$ 11 is an unnatural one and may be regarded as questionable; it would not have been accepted if it had not been that the reflection from it was followed by a distinct reflection making the proper angle for the pyramid *p*. The pyramid *n* is in two levels separated by the zone of small faces *f*, *z*, *y*; to the right of this zone, see fig. 15, we notice both *o* and *n*, to the left only *n*.

Recapitulation.

The measurements which have thus far been given were obtained from thirteen crystals; from the material which was sent to New Haven a few other fragmentary ones could have been measured but they did not seem to offer anything new or of special interest. Owing to the curious combination of stalactite and crystal there is no decided crystallographic habit which can be mentioned as characteristic of our mineral nor in those specimens which are decidedly stalactitic is there any definite relation between the axis of the stalactite and the crystallographic axes for in figures 11, 12 and 13 the faces which terminate the stalactite mostly intersect the end of the vertical axis and in fig. 4 its positive end; in figs. 5 and 6 they intersect the negative end of the macro axis and in fig. 7 its positive end.

In criticising the crystallographic results it must be borne in mind that none of the crystal were well suited for measure-

ment, as they were without exception pseudomorphs and the faces had lost to a greater or less extent the high polish and luster of ordinary crystal faces. Many of the measurements were therefore made from very indistinct reflections, being mere "schimmer" measurements and in such cases the angles vary at times more than one degree from the calculated. Among all the measurements the agreement between the measured and calculated angles is very satisfactory, considering the nature of the material, while the zonal relation of the faces, as observed on the goniometer, was throughout very perfect. From the following statement a good idea of the frequency of the faces can be obtained: leaving out of consideration two stalactites, No. 2, terminated by only three faces, and No. 3, by only two, we find that the faces, *c*, 001, *b*, 010 and *p*, $1\bar{1}1$ were identified on all of the remaining eleven crystals; M, $1\bar{1}0$ on ten; *m*, 110 on nine; *e*, $0\bar{2}1$ and *r*, $1\bar{3}2$ on eight; *d*, 021 on seven; *x*, $\bar{1}32$ on six; *y*, $\bar{1}11$ and *o*, $\bar{1}\bar{1}2$ on four; *n*, $\bar{1}\bar{1}1$ and *h*, 150 on three; *k*, $3\bar{1}0$, *q*, $3\bar{1}2$, *z*, $\bar{3}12$, π, $\bar{1}\bar{5}2$ and ρ, $\bar{1}\bar{3}1$ on two and *l*, $1\bar{7}0$, *s*, $1\bar{7}2$, *f*, $\bar{2}01$, P, 111, τ, 10, $\bar{1}\bar{2}$, 11 and *w*, $\bar{5}$, 151 on only one crystal. Owing to the pseudomorphous nature of the mineral we cannot give any statement of the optical properties of the lansfordite. The cleavage of the lansfordite, which Dr. Genth mentioned in the original article as being very good is probably basal, which we infer from the fact that the partially altered crystal No. 11 broke near its base, where it was wholy altered, parallel to the basal plane and lower down where the mineral was only partially altered the decomposition seemed to be advancing along planes, probably cleavage, parallel to the base.

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Mineralogical Laboratory, Sheffield Scientific School, Dec. 10th, 1889.

Art. XX.— *Weber's Law of Thermal Radiation*; by William Ferrel.

1. In a previous paper on the Law of Thermal Radiation,* which will be referred to in what follows as paper A, the laws of Dulong and Petit and of Stefan were examined, and it was shown from comparisons with the results of experiment that neither of these laws holds generally for all temperatures of the radiating body, but that either, and especially the latter, holds through a considerable range of the ordinary temperatures of experiment and observation, and that for higher or lower temperatures, a change in the values of the constants is

* This Journal, xxxviii, July, 1889.

required. We come now to a similar examination of Weber's new law.*

2. Putting s for the rate with which energy is emitted in all directions by the rays of wave-length λ from the surface F of the radiating body at the absolute temperature T, he assumes

$$s = c\pi F \frac{1}{\lambda^5} \cdot e^{aT} - \frac{1}{b^2 T^2 \lambda^2} \qquad (1)$$

in which $a = 0043$ and b and c are constants which vary with different substances. This makes s increase with the increase of T more rapidly for the rays of short than of long wave-lengths, as it should, and is found to represent approximately the experimental results obtained by Langley. But experiments on the radiation of the separate wave-lengths are too few yet to furnish data for an accurate test of this formula.

3. Putting now S for the rate with which heat of all wave-lengths is radiated, he gets from the preceding expression of s by integration,

$$S = \int_0^\infty s d\lambda = CFT \cdot e^{aT}. \qquad (2)$$

This gives for the rate with which the surface F of a body at absolute temperature T loses heat when placed in an inclosure of absolute temperature T_1, in Weber's notation,

$$\Delta S_{T, T_1} = CFT_1 \cdot e^{aT_1} \left\{ \frac{T}{T_1} \cdot e^{a(T-T_1)} - 1 \right\}. \qquad (3)$$

The value of C in these expressions is a function of b and c in (1) above, and therefore is different in different substances.

The values of the first member of this expression being obtained from experiment with an inclosure of absolute temperature T, for a number of values of T extending through a considerable range, the test of the formula is that we must have

$$\frac{\Delta S_{T, T_1}}{\frac{T}{T_1} \cdot e^{a(T-T_1)} - 1} = CFT_1 \cdot e^{aT_1} = \text{a constant}. \qquad (4)$$

4. In testing the formula Weber used the results of Schleiermacher's experiments,† in which the radiation was determined by the amount of electric energy consumed in maintaining a platinum wire at a given temperature, stretched in vacuo in the interior of a tube. In one of the sets of experiments a bright wire, $0{\cdot}197^{mm}$ in diameter, was used, and in the other a wire coated with the black oxide of copper, $0{\cdot}296^{mm}$ in diame-

* Sitzungsb. der Kön. Preuss. Ak. der Wissenschaften, 1888 (2), 933.

† Wied. Annalen, xxvi, 287.

ter. With the results of these experiments the first member of (4) was found to be very nearly a constant through a range of temperature of about 700°, which is remarkable for so great a range.

Schleiermacher has himself tested Weber's formula in the same way by using the results of his more recent experiments by the electric method,* and found the formula fairly satisfactory, but these experiments extended through a range of not more than 150°, and less in the one case.

5. The formula, so far, has been compared with the results only of Schleiermacher's experiments, but when we come to test it by means of experimental results in which the absolute rate of losing heat is determined from the observed rate of cooling of heated bodies of known thermal capacity, and the relative rate, from the galvanometer needle of the thermopile, the law is not so satisfactory.

If we take the corrected rates of cooling R obtained in Dulong and Petit's experiments, given in the table of § 4, paper A, and given here in the second column of the following table, in which $T_1=273°$, we get the corresponding values of $CFT_1 . e^{aT_1}$ with $a=·0043$ as given in Weber's formula.

T	$\Delta S_{T, T_1}$	$CFT_1 . e^{aT_1}$ with	
		$a=·0043$	$a=·0064$
353°	1·48°	1·799	1·160
373	1·96	1·782	9·906
393	2·60	1·842	0·922
413	3·38	1·917	0·964
433	4·31	2·000	1·005
453	5·43	2·090	1·062
473	6·64	2·145	1 035
493	7·95	2·178	0·955
513	9·74	2·279	1·003

The values in the second column here are rates of cooling and not the rates of given out heat in absolute measure as the formula requires, but the two are sensibly proportional since the capacity of mercury for heat changes but little with change of temperature. The values of the third column, therefore, should still be a constant. It is seen that this is far from being the case, but that there is an increase with increase of temperature, indicating that a greater value of a is required in the formula to satisfy the condition of (4), which the law requires. But if we increase the value of this constant about one half, or to ·0064, we get the results of the last column of the table,

* Wied. Annalen, xxxiv, 623.

which are much more satisfactory, but not entirely so, since some of the individual values differ as much as $\frac{1}{11}$ part from the mean of all, 1·001, and the first one in the column much more. The law is not nearly as well satisfied as either of the expressions given in the table of § 4, paper A.

6. Again, let us take the relative measures of the loss of heat indicated by the deviations of the galvanometer needle of the thermopile in Rosetti's experiments, given in §10, paper A, and also contained in the second column of the following table, in which $T_1 = 273 + 23{\cdot}8 = 296{\cdot}8°$.

T	$\Delta S_{T, T_1}$	$CFT_1 \cdot e^{aT_1}$ with	
		$a = {\cdot}0043$	$a = {\cdot}0059$
329·6°	10·0	36·0	28·8
369·6	29·5	42·7	32·3
389·6	42·8	45 5	33·7
409·6	55·0	45·2	32·6
429·6	72·5	47·4	33·4
449·6	91·5	48·6	33·5
469·6	116·7	51·3	34·5
489·6	141·9	52·3	34·2
509·6	169·5	52·9	33·7
529·6	204·0	54·4	33·7
549·6	239·5	54·9	33·1
569 6	283·5	56·1	33·0

It is seen that with Weber's value of $a = {\cdot}0043$ the condition of (4) is not even approximately satisfied, but by changing it to ·0059, the results of the last column of the table indicate that it is approximately satisfied, neglecting the first place in the column, through a range of 200°; but Weber's formula, even with this great change in the value of the constant, does not satisfy the results of experiment nearly so well as the expression at the head of the last column of the table of §10, paper A, since some of the numbers of the last column above vary from the mean as much as $\frac{1}{30}$ part and more.

T	$\Delta S_{T, T_1}$	$CFT_1 \cdot e^{aT_1}$ with	
		$a = {\cdot}0043$	$a = {\cdot}0070$
321·2	.02049	·0706	·0497
328·5	·02601	·0721	·0501
354·0	·04794	·0754	·0500

7. With the values of the differences of the rates of cooling of a black and a silvered thermometer bulb, as observed by De la Provostaye and Desains we get, as in the preceding cases,

the accompanying table of results, in which the second column contains the differences of the rates of cooling of the two thermometers, and in which $T_1=287{\cdot}7°$.

In this case, also, the value of $a=·0043$ is very much too small and the value of ·007 is required to satisfy the condition of (4), which requires the last member to be a constant.

8. From what precedes it is seen that the value of a in Weber's formula which satisfies (4) with Schleiermacher's experimental results, in which the rate of losing heat in the heated body is determined by the electric method, does not satisfy it where the rate of the loss of heat is ascertained from the observed rate of cooling of a body of known heat capacity, or by the deviations of the galvanometer needle of the thermopile; and that the value of a required in the last two cases is much greater than in the former. It also appears that the value of a required in the last two cases increases with decrease of temperature. For in the case of the table of § 6, in which the range of temperature, neglecting the first two places, is from 389·6° to 569·6°, the mean being 479 6°, and through which the values of the last column of the table are approximately equal, the value of $a=·0059$ is required, while in the case of the table of § 5, in which the range of temperature is from 353° to 513°, the mean being 433°, the value of a required is ·0064. Again, in § 7 where the average temperature is only 337·7, the still greater value of $a=·007$ is required to make the numbers of the last column approximately equal.

That the value of a in Weber's formula must increase with decrease of the temperature in Rosetti's experiments is seen from the values in the last column of the table of § 6, in which the numbers increase for the lower and decrease for the higher temperatures, which indicates that the value of a in the formula must be greater for the lower than for the higher temperatures. .

9. It has been shown in § 7, paper A, that if we multiply the rates of cooling in the experiments of Dulong and Petit by 0·4516, we get the rate of losing heat by radiation from each unit of surface. Hence, multiplying the mean value of $CFT_1e^{aT_1}$ in the last column of the table of § 5, which is 1·001, into 0·4516, we get

$$273\ Ce^{273a}=0{\cdot}452$$

the value of F being unity in this case, and the first member of this equation is the expression of the rate of radiating heat from each unit of surface at the temperature of $T_1=273°$ which in §7, paper A, was denoted by m and found to be 0·7188 from Dulong and Petit's formula with $a=1{\cdot}0082$, and 0·3296 from Stefan's law with $e=4{\cdot}2$.

From (3) we get with the value of 273 Ce^{273} above and putting F=1,

$$\Delta S_{373,\,273}=0{\cdot}452\left(\frac{373}{273}e^{100a}-1\right) \qquad (5)$$

This expression with $a=\cdot0064$, which was required to satisfy the observations in the table of § 5 and the condition of (4), we get

$$\Delta S_{373,\,273}=0{\cdot}7192$$

This was denoted by $H_{100}-H_0$ in § 7, paper A, and was found from the experiments of Dulong and Petit to be 0·9092 by the one formula and 0·8926 by the other. It was also determined by Lehnebach directly from experiment to be 0·912. This quantity, then, must be regarded as being pretty accurately determined, and therefore the law of Weber, which gives only 0·7192 when applied to the same experiments does not hold for the temperatures between 0° and 100°, even with the value of $a=\cdot0064$ instead of ·0043, and indicates that the value of a must be still greater for this range of lower temperatures; and this is in accordance with what we have already shown, namely, that the lower the temperature, the greater must be the value of a.

10. While nearly the same values of a in Weber's formula are required for all temperatures in Schleiermacher's experiments in which the loss of energy by the wire is measured by the electric method, in all other experiments in which it is measured by the observed rates of cooling and by the thermopile, the value of a required seems to be much greater, and to increase with decrease of temperature. This may arise in part from the uncertainty in the temperatures of the wire as determined from the observed resistances at different temperatures, especially for high temperatures, but a more probable explanation is found in the want of a perfect vacuum in the tubes through which the wires, heated by the electric current, are stretched; for the heat conduction from small wires is enormous for all ordinary, and even very low, air pressures, and so it is perhaps impossible to have a vacuum so nearly perfect, and to maintain it during the whole time of the experiments, that the amount of heat lost by conduction is so small in comparison with that lost by radiation that it may be neglected in comparison.

Putting

h=the heat conducted from each unit of surface of the wire,

r_1, r_2=the radii of the wire and the internal part of the tube respectively,

τ_1, τ_2=the corresponding temperatures at r_1 and r_2 from the center,

$\delta = \tau_1 - \tau_2$,
K_0 = the constant of conductivity of air at $\tau = 0°$,
α = the temperature coefficient of the conductivity, we have

$$h = \frac{MK_0}{r_1 \log \frac{r_2}{r_1}} \left(1 + \alpha\tau_2 + \tfrac{1}{2}\alpha\delta\right)\delta \qquad (6)$$

Stefan has used the value of $K_0 = \cdot 000054$, where the unit of time is the second, and $\alpha = \cdot 0027$.

11. It is readily seen from this formula that with very small values of r_1 the values of h become very large. For instance, the last experiments of Schleiermacher, referred to in §4, were made with wires $0 \cdot 405^{mm}$ in diameter, the internal diameter of the tube being $24 \cdot 2^{mm}$. Putting, therefore, in centimeters $r_1 = \cdot 02$ and $r_2 = 1 \cdot 2$, the preceding formula gives for $\delta = 1$, and $\tau_2 = 0$, $h = 0 \cdot 00064$. But we have found in § 22, paper A, for the heat lost by radiation from a unit of glass surface with $\delta = 1$, $E = \cdot 0056$ nearly on the average from all experiments, and by means of several formula, which reduced to the second unit is $\cdot 000093$, a quantity which differs but little from the values found experimentally by Winkelmann and by Kundt and Warburg. But the radiativity of platinum is only about $\frac{1}{6}$ of that of glass, and hence for platinum we have, for the second unit of time, $E = \cdot 00001$ very nearly. Hence, in these experiments of Schleiermacher the heat of the wire lost by conduction with ordinary, or even with very small air pressure, would have been 64 times that lost by radiation, where the difference between the temperature of the wire and that of the tube is small. It is reasonable to suppose, therefore, that it is necessary for the tension of air in the tube to be reduced to an exceedingly low one, in order that the heat *conducted* may be neglected in comparison with that lost by *radiation*, and this is especially so in the case of a bright wire, in which the radiation is comparatively small. And if the tension is not so reduced, but a part of the heat lost by the wire is due to conduction, it is evident that the rate of increase with increase of temperature is diminished, since the increase in the part due to conduction, as is seen from (6), is but little more than the first power of δ, the difference between the temperature of the heated body and the enclosure, and very uncertain for high temperatures, and since the value of the temperature coefficent has been determined for ordinary temperatures only, while from a mere inspection of the various formulæ which should represent the rate of loss of heat, or from the experimental values of ΔS_{TT_1} in the preceding tables, it is seen that the rate of increase with increase of temperature is much greater. In this case a smaller value of a in Weber's formula would be re-

quired than if the loss of heat in the wire depended upon radiation only.

12. That there is such a decrease of the rate of losing heat with increase of temperature, where there is only an exceedingly small air tension left in the tube, is shown by the asymptotic experiments of Mr. Bottomly.* Taking his values of C^2R/Js for the temperatures of the wire at 408° and 505° C. respectively, the temperature of the inclosure or water jacket being 16°, and coördinating them graphically with the corresponding pressures, and smoothing off a little the irregularities, as usual, in drawing a curve through the different points determined by the coördinates, the values of C^2R/Js in the following table, corresponding to the several tensions in the first column, are found:

Air-tension.	C^2R/Js at		Ratio.
	408°	505°	
0·10mm	0·125	0·172	1·38
·09	·117	·162	1·39
·08	·109	·153	1·40
·07	·102	·144	1·41
·06	·095	·135	1·42
·05	·086	·127	1·44
·04	·080	·118	1·47
·03	·071	·108	1·52
·02	·061	·096	1·57
·01	·050	·084	1·68
·00	·037	·072	1·92

From this table it is seen that with an air-tension of only 0·1mm in the tube the rate of loss of heat in an increase of the temperature of the wire from 408° to 505° is as 1 to 1·38, while for a vacuum, with the numbers here given, it is as 1 to 1·92. Hence in the former case Weber's formula, in order to represent these results, would require a much smaller value of a than in the case of a perfect vacuum. And for an air-tension of only 0·01mm the rate of increase is as 1 to 1·68, which is still much less than in the case of a perfect vacuum, and the value of a in Weber's formula would still have to be much less. It should be here stated that the numbers in the last line of the table, for a perfect vacuum, are uncertain, on account of the uncertainties in the measurements of so low tensions in approximating to a vacuum.

13. The effect of a very small air-tension upon the rate of heating or cooling of a thermometer bulb in a glass globe of 1·5 inches in diameter, is shown by the experiments of Mr. Crookes.† The temperature of the inclosure being kept at 65°,

* Phil. Trans., vol. clxxviii, p. 129, 1888.
† *Nature*, vol. xxiii, 1880–1881, p. 234.

with an air-tension of 5M (·0038^{mm}), the time required for the bulb to be heated from 25° to 50° was 322 seconds; but when the tension was reduced to 2M (·00152^{mm}), the time was 412 seconds. With a perfect vacuum the time, of course, would have been still much greater. The diameter of the bulb is not given, but by the formula of §5, paper A, with a very small bulb, the effect of conduction would have been much greater.

ART. XXI.—*Tracks of organic origin in rocks of the Animikie group;* by A. R. C. SELWYN, Director of the Geological and Natural History Survey of Canada (letter to the Editors, dated Jan. 7, 1890).

THE discovery of even traces of fossils, or what are supposed to be such, in the Animikie rocks of Lake Superior, is an interesting and important fact which I wish to announce through the medium of this Journal. The specimens were collected by Mr. E. D. Ingall of this Survey, and were submitted to Mr. Matthew of St. John, N. B., for examination and comparison. Mr. Matthew has furnished me with the accompanying very interesting statement of his views respecting them. I have long held the view that the black Animikie shales represented the Lower Cambrian of the Atlantic border, and I have little doubt that sooner or later the Paradoxides and Olenellus fauna will be found in them. They are quite distinct from and unconformable on the Huronian.

DEAR SIR: I have examined the pieces of flagstone and shale of the Animikie group, bearing impressions of various kinds, which you were kind enough to send me for comparison with markings on the flags and shales of the St. John group and other Cambrian rocks.

These have greatly interested me, and while some are too indefinite to be of value for such comparison, others are undoubtedly of similar origin with characteristic tracks of the Cambrian rocks here.

I should observe, however, that the vertical range of these peculiar tracks of the oldest Palæozoic rocks is not known, and I can only speak of the Animikie forms in comparison with such markings as they appear in the Cambrian sediment of this region.

I would refer especially to two types of tracks which are present on the pieces sent for examination. One of these recalls objects which have been referred to *Eophyton*, but incorrectly, as there are two resembling types of tracks in the Lower Cambrian rocks which have been classed under Eophyton, of which one only is the true Eophyton of Torell.

Another piece of flag has an impression similar to some which have been referred to *Taonurus*, etc., but which I think are not seaweeds. These as well as Eophyton appear to me to be tracks made in the mud by marine animals.

This Taonurus like impression exhibits a group of striæ converging from a furrowed margin, and becoming more or less parallel and approximate. The markings are such as would be made by an animal having numerous tentacles or arms, furnished with hooks or horny protuberances at the extremity. If such arms were spread and pressed down upon the muddy bottom, and gradually drawn together as the animal moved onward, they would make such markings as are found on this piece of flagstone.

A radiate animal might make a track like this, and since remains of such creatures (Acalephs and Echinoids) have been reported from a lower horizon in the Cambrian rocks of Sweden, than that which, in this region, carries the resembling impressions, one may conjecture that these tracks have been made by a radiate animal of some kind.

The resembling impressions at St. John are found on the layers of fine sandstone and shale which belong to Bands *a* and *c* of Division 2 of the St. John group. The equivalent of Division 2 in Europe is the Olenus Zone, the Mæntwrog and Ffestiniog groups of Wales.

Our best examples show spindle-shaped furrows, radially arranged near the margin of the track, larger and flatter in the bottom than those of the Animikie example. In ours the furrows narrow into striæ which converge and become nearly parallel. The Animikie form shows markings made by three groups of tentacles, all moving in nearly the same direction, but not applied to the sea-bottom simultaneously.

I propose for such tracks the name *Taonichnites*.

Another piece of flagstone from the Animikie group has markings due to an animal entirely different from that which made the markings above described. These are straight and parallel, and in sets which often cross at a small angle. They look exceedingly like the glacial striæ found on rock surfaces, in which, in a similar manner, the different sets interfere with each other.

I have studied the variations of these markings found in the rocks at St. John, and think they indicate an animal which had arms placed on each side of the body, at least three in each set, and that these arms were beset with small spines or hooks. When moving along the bottom the animal threw its arms backward and outward and then drew them forward, thus making as it advanced the straight parallel striæ so characteristic of the principal part of its track.

The manner in which it spread its arms was therefore the reverse of that pursued by the creature which made the Taonichnite track.

After a consideration of the various forms of this track and the circumstances under which it occurs, I can think of no animal except one related to the Squid or Calamary capable of making it.

These impressions are found near the base of the St. John group and through its Division 2, or in other words, in the Olenellus and Olenus Zones; and I would suggest for them the name *Ctenichnites*. A fuller description of these tracks with figures will be given in a paper now in preparation for the Royal Society of Canada.

Both of the forms of track above described belong to shallow sandy and muddy shores, and must have been comparatively common on the Cambrian coasts, where sand and mud beds alternated. On the sands unless they are muddy sands the tracks were only faintly made, but in the soft fine mud they are most prominent. They are most easily recognized by the mould of the track on the under side of beds of sandstone whose sand has been deposited in and over the impressions the animal made in the mud beneath. These moulds are often strikingly distinct, more so than the tracks themselves.

Eophyton (properly Eoichnites) bears considerable resemblance to Ctenichnites, but in the examples of Eophyton which I have seen, we seldom fail to recognize a depressed groove or broad shallow furrow, which Torell appears to have mistaken for the stem or trunk of a plant.

I should add that in the Ctenichnites of the Acadian Cambrian rocks as known to me the striæ are coarser and more widely spread than those of the Animikie example which you sent me.

I remain, yours, etc.,

G. F. MATTHEW.

St. John, New Brunswick, January 3, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Periodic Law.*—In his Faraday lecture before the Chemical Society, Mendeléeff took for his subject the periodic law of the chemical elements. In March, 1869, he had enunciated his conclusions as follows: (1) The elements if arranged according to their atomic masses, exhibit an evident *periodicity* of properties; (2) elements which are similar as regards their chemical properties, have atomic masses which are either of nearly the

same value (e. g., platinum, iridium, osmium) or which increase regularly (e. g., potassium, rubidium, cæsium); (3) the arrangement of the elements in the order of their atomic masses corresponds to their so-called *valencies* as well as, to some extent, to their distinctive chemical properties; (4) the elements which are the most widely diffused have *small* atomic masses; (5) the *magnitude* of the atomic mass determines the character of the element just as the magnitude of the molecule determines the character of a compound body; (6) we must expect the discovery of many yet *unknown* elements—for example, elements analogous to aluminum and silicon, whose atomic mass would be between 65 and 75; (7) the atomic mass of an element may sometimes be amended by a knowledge of those of the contiguous elements; i. e., the atomic mass of tellurium must be between 123 and 126 and cannot be 128; and (8) certain characteristic properties of the elements can be foretold from their atomic masses. And in 1889, twenty years afterwards these conclusions may still be considered as expressing the essence of the now well known periodic law. Three sets of data had contributed to make the discovery of this law possible. In the first place the true conception of an atom had been arrived at and real atomic masses had been reached. The relation between K 39 and Ca 20, between Rb 85 and Sr 43·5, between Cs 133 and Ba 68·5 fails entirely to show the consecutiveness in atomic mass, which becomes so apparent when Ca is 40, Sr is 87 and Ba is 137. In the second place it had already become evident that the relations between the atomic masses of analogous elements were governed by some general and simple laws; in proof of which the classifications of Cooke, Dumas, Strecker and others may be mentioned. Among these he includes Newland's "Law of Octaves;" which although suggestive, included elements having no apparent connection with each other in the same octave, and which contained occasionally ten elements in the octave instead of eight. The third circumstance favoring the discovery of the law of periodicity was the accumulation of new information respecting the rarer elements, disclosing their many-sided relations to the other elements and to each other; among specially important researches being those of Marignac on columbium and of Roscoe on vanadium. When the striking analogies between vanadium and phosphorus on the one hand and between vanadium and chromium on the other had become apparent, and when V 51 had been compared with Cr 52, Cb 94 with Mo 96 and Ta 192 with W 194, or P 31 with S 32, As 75 with Se 79 and Sb 120 with Te 125, there remained but a step to the discovery of the law of periodicity. Mendeléeff then passes to an attempt to answer the question wherein lies the secret of the special importance of the periodic law, which has already given to chemistry unexpected aid and which promises to be far more fruitful and to impress upon several branches of chemical research a peculiar and original stamp. As soon as the law appeared, it demanded a revision of many

facts supposed to be well established; and the legitimacy of the law, as a deduction from verified facts, has been proved by the completeness with which this requirement has been met. Periodic functions have long been known and have long been used for the purpose of expressing changes which are dependent on variations of time and space. "A like periodic function became evident in the case of the elements, depending on the mass of the atom. The primary conception of the masses of bodies or of the masses of atoms belongs to a category which the present state of science forbids us to discuss because as yet we have no means of dissecting or analyzing the conception. All that was known of functions dependent on masses derived its origin from Galileo and Newton and indicated that such functions either decrease or increase with the increase of mass like the attraction of celestial bodies. The numerical expression of the phenomena was always found to be proportional to the mass and in no case was an increase of mass followed by a recurrence of properties such as is disclosed by the periodic law of the elements. This constituted such a novelty in the study of the phenomena of nature that although it did not lift the evil which conceals the true conception of mass, it nevertheless indicated that the explanation of that conception must be searched for in the masses of the atoms; the more so as all masses are nothing but aggregations or additions of chemical atoms which would be best described as chemical individuals." "The periodic law has shown that our chemical individuals display a harmonic periodicity of properties dependent on their masses." "If we mark on the axis of abscissas a series of lengths proportional to angles and then lay off ordinates proportional to sines or other trigonometrical functions, we get periodic curves of a harmonic character. So it might seem at first sight that with the increase of atomic masses the function of the properties of the elements should also vary in the same harmonic way. But in this case there is no such continuous change as in the curves just referred to because the periods do not contain the infinite number of points constituting a curve, but only a *finite* number of such points. An example will better illustrate this view. The atomic masses—

Ag 108 Cd 112 In 113 Sn 118 Sb 120 Te 125 I 127

steadily increase and their increase is accompanied by a modification of many properties which constitute the essence of the periodic law. Thus for example the densities of the above elements decrease steadily being respectively

10·5 8·6 7·4 7·2 6·7 6·4 4·9

while their oxides contain an increasing quantity of oxygen:—

Ag_2O CdO_2 In_2O_3 Sn_2O_4 Sb_2O_5 Te_2O_6 I_2O_7

But to connect by a curve the summits of the ordinates expressing any of these properties would involve the rejection of Dalton's law of multiple proportions. Not only are there no in-

termediate elements between silver which gives AgCl and cadmium which gives $CdCl_2$, but according to the very essence of the periodic law there can be none; in fact a uniform curve would be inapplicable in such a case, as it would lead us to expect elements possessed of special properties at any point of the curve. The periods of the elements have thus a character very different from those which are so simply represented by geometers. They correspond to points, to numbers, to sudden changes of the masses and not to a continuous evolution. In these sudden changes destitute of intermediate steps or positions, in the absence of elements intermediate between say silver and cadmium or aluminum and silicon, we must recognize a problem to which no direct application of the analysis of the infinitely small can be made. Therefore neither the trigonometrical functions proposed by Ridberg and Flavitzky nor the pendulum-oscillations suggested by Crookes, nor the cubical curves of the Rev. Mr. Haughton, which have been proposed for expressing the periodic law, can, from the nature of the case, represent the periods of the chemical elements."

With reference to the bearing of the periodic law on the question of a primary matter, Mendeléeff says: The periodic law based as it is on the solid and wholesome ground of experimental research, has been evolved independently of any conception as to the nature of the elements; it does not in the least originate in the idea of a unique matter; and it has no historical connection with that relic of the torments of classical thought, and therefore it affords no more indication of the unity of matter or of the compound character of our elements than the law of Avogadro or the law of specific heats or even the conclusions of spectrum analysis. None of the advocates of unique matter have ever tried to explain the law from the standpoint of ideas taken from a remote antiquity when it was found convenient to admit the existence of many gods—and of a unique matter."

In concluding, the lecture discusses the enlargement of the range of vision by the periodic law. For the first time it enabled us to perceive undiscovered elements at a distance hitherto unaccessible to chemical vision and to define their properties; as is seen in gallium, scandium, and germanium. A fourth element he now foresees analogous to tellurium, which he calls dui-tellurium, Dt, having an atomic mass of 212 and forming an oxide DtO_3. It is an easily fusible crystalline non-volatile metal of a gray color, having a density of about 9·3, and giving an oxide DtO_2 equally endowed with feeble acid and basic properties. On active oxidation it gives DtO_3 which resembles PbO_2 and Bi_2O_5 and is unstable. The hydride will be less stable than H_2Te. Its compounds will be easily reduced and it will form characteristic alloys. Attention is then called to the way in which the periodic law has compelled a modification of both atomic masses and valencies, as in the cases of indium, cerium, yttrium, beryllium, thorium and uranium, and has detected errors in atomic

masses, as in the case of tellurium, titanium and platinum. Moreover the periodic law has detected periodicity in the physical properties of bodies; so that density, elasticity, tenacity, fusing point, heat of formation, magnetic properties and the like are now deducible from it. As to chemical properties, the periodic law shows not only that the increase of the power of combining with oxygen in the elements is accompanied by a corresponding decrease in their power of combining with hydrogen, but also that there is a limit to oxidation just as there is to hydrogenation; so that just as CH_4 and SiH_4 represent the highest hydrides so RuO_4 and OsO_4 represent the highest oxides. Moreover this law has demonstrated that the maximum extent to which different non-metals enter into combination with oxygen is determined by the extent to which they combine with hydrogen, the sum of the number of equivalents of both being always equal to eight. Thus Cl forms ClH and Cl_2O_7; and since O is bivalent each chlorine atom has seven equivalents in the oxide and one in the hydride, making 8. So sulphur which fixes two equivalents of hydrogen cannot combine with more than six equivalents or two atoms, of oxygen. As to the peroxides, they have a character special to themselves. The peroxide form of sulphur (the so-called persulphuric acid) stands in the same relation to sulphuric acid that hydrogen peroxide stands in to water:

$H(OH)$ or H_2O is to (OH) (OH) or H_2O_2 as $H(HSO_4)$ or H_2SO_4 is to (HSO_4) (HSO_4) or $H_2S_2O_8$.

So that the periodic law is strengthened rather than weakened by the existence of peroxides. In proof that the law extends to compounds, a double list of oxides is given with their densities and specific volumes, ranging from Na_2O and K_2O to S_2O_6 and Cr_2O_6. In a fourth column the differences are given between the volume of the oxygen compound and that of the parent element, divided by the number of oxygen atoms in the compound; and these differences steadily increase with the increase of oxygen.—*J. Chem. Soc.*, lv, 634, October, 1889. G. F. B.

2. *On Sonorous Sand in the Peninsula of Sinai;* by H. Carrington Bolton.—The author describes the results of his personal observations on the sonorous sands of Jebel Nagous, Arabia Petræa. The paper is in continuation of two others on Musical Sand presented jointly with Dr. A. A. Julien at the meetings of the American Association in Minneapolis and Philadelphia.

The isolated mountain of Jebel Nagous is situated about four and one-half hours northwest of Tor on the Gulf of Suez. On the steep slopes of this mountain rest several large banks of sand; one of these, called the Seetzen's Bell Slope, after its discoverer, emits distinct musical sounds whenever the sand slides down the incline either spontaneously or through the agency of man. The mountain consists of massive white sandstone carrying quartz pebbles and veins; it is about three miles long and 1,200 feet high. The Bell Slope measures 260 feet across the base, five or

six feet across the top and is 390 feet high; it is bounded by nearly vertical walls of sandstone. The yellowish white sand rests on the rocks at the high angle of 31°, is very fine grained, and composed chiefly of quartz and calcareous sandstone. The grains are well rounded to subangular, and silt is notably absent. As the sand reposes at a high angle it possesses a curious mobility which causes it to flow down the incline like soft pitch or molasses; the sand above the point of disturbance falls into the depression and this depression advances up the slope at the same time. This downward flow takes place spontaneously whenever the sand, forced up the incline by the violent winds, accumulates in such quantity as to exceed the angle of rest. The movement is accompanied by a strong vibration and by a musical tone resembling the lowest bass note of an organ with a tremolo stop. The larger the bulk of sand moved the louder the sound; it is by no means so sensitive as the sand of so-called singing beaches (which the author has described elsewhere), and fails to emit sounds when struck with the hand or clapped together in a bag. The vertical cliffs on either side yield an echo that may magnify and prolong the sounds, which were loud enough to be heard several hundred feet. The peak of Jebel Nagous rises above the slope to the height of 955 feet above the sea level. The Bedouins of the region account for the acoustic phenomenon by attributing it to the *Nagous* or wooden gong of a subterranean monastery in the heart of the mountain, and claim that the sounds can only be heard at the hours of prayers.

Several other sandbanks presenting a similar appearance to the eye were tested but gave out no musical sounds whatever. Microscopical examination of these sands shows that they contain much silt, which prevents the vibrations necessary to yield the sounds. Further, the author after testing many sandbanks on the journey northward to Suez, discovered banks of sonorous sand resting on low cliffs a quarter of a mile long at Wadi Werdân about a day and a half from Suez, by camels, on hillocks called Ojrat Ramadân. The sand blown from the extensive plains to the north, falls over the southern face and rests at two angles, 31° at the top and 21° or less near the base. Wherever it possesses the mobility before described it emits a distinct musical note on being disturbed. The highest bank measures only sixty feet on the incline, and it is not probable that the sounds can occur spontaneously. Dr. Julien finds that at the new locality named by him Bolton's Bell Slope, the sand is chiefly quartz, with a larger proportion of calcareous sandstone than at Jebel Nagous. The size of the grains of quartz varies from 0·11 to 0·42^{mm} and of sandstone 0·11 to 0·34^{mm}, the average being smaller than that of the sand grains on Jebel Nagous. Like the latter it is very free from silt.

After alluding to the various hypotheses advanced by different authors to explain the phenomena described, the author goes on to mention the explanation arrived at by himself and Dr. Julien. The cause of sonorousness in the sands of singing beaches

and of deserts is believed to be connected with thin pellicles or films of air, or of gases thence derived, deposited and condensed upon the surface of the sand-grains during gradual evaporation after wetting by the seas, lakes, or by rains. By virtue of these films the sand-grains become separated by elastic cushions of condensed gases, capable of considerable vibration, and whose thickness has been approximately determined. The extent of the vibration and the volume and pitch of the sound thereby produced, after any quick disturbance of the sand, is also found to be largely dependent upon the forms, structures and surfaces of the sand grains, and especially upon their purity or freedom from fine silt or dust. Though the environment of the sand on beaches and in the desert differs greatly as respects moisture, this above theory is regarded applicable to both. Water is not wholly lacking even in the desert to aid in the chemical cleansing of the sand grains, and the powerful winds accomplish the work of sorting and winnowing done by the waves elsewhere. The fineness of the grains at the Bell Slopes makes the displacement of a very large amount of sand necessary for the production of sound, while the coarser particles on the beaches yield a resonance on a smaller provocation. The pitch of the musical notes produced on sea beaches is directly proportional to the mass of sand moved, the greater the mass the lower the tones; on the Bell Slopes in the desert the large mass moved, yields a very deep note.—*Amer. Assoc. Adv. Science*, vol. xxxviii.

3. *Electromagnetic effect of Convection.*—F. Himstedt has repeated Rowland's experiments upon this subject and concludes that electric convection can produce electromagnetic effects. Rowland's results have been questioned by certain observers, among them, by Lecher (Rep. d. Phys., xx, p. 151, 1884). Himstedt believes that Lecher's apparatus was not sufficiently sensitive to obtain the phenomena. During the progress of his work, Himstedt discovered that ebonite shows traces of magnetism and therefore he used glass discs. The method was the same as that employed by Rowland. Two glass discs, rubbed with graphite, and strongly charged were set in revolution, one on each side of an astatic combination. The speed of the discs was from 60 to 170 revolutions per second. In general Himstedt confirms Rowland's work. He does not however confirm Rowland's observation that a difference is called forth by changing the direction of rotation. No difference could be observed.—*Ann. der Physik und Chemie*, 1889, No. 12, pp. 560–573. J. T.

4. *Mechanical equivalent of Light.*—H. O. Tumlirz states his results as follows: A surface of 1 square centimeter placed at a distance of 1 meter from the planes of an Amylacetate lamp—in such a way that the normal to the surface is horizontal and passes through the middle of the plane—receives per second a quantity of light which expressed in units of work is

$$\frac{15{\cdot}15\ (cm^2 g\ \mathrm{sec}^{-2})}{1\ \mathrm{sec}}$$

If the pupil of an eye is placed at the surface its aperture is 3^{mm} it receives in each second,

$\frac{1\ (cm^2 g\ \sec^{-2})}{1\ \sec}$ units of work. This quantity of work would require 1 year 89 days to raise 1 gram of water 1° C. A comparison of the light of the sun and that of stars of various orders of magnitude is appended to the paper.—*Ann. der Physik und Chemie*, 1889, No. 12, pp. 640–662. J. T.

5. *The Bolometer.*—R. Von Helmholtz constructed a bolometer of which all four branches of the Wheatstone's bridge were contained in the cylindrical case of the instrument and two branches of the bridge were exposed to the source of light. The theory indicates that the resistance of the four equal branches of the bolometer balance should be as great as possible (with suitable galvanometer resistance) that this resistance should be in the form of blackened strips: that these strips should receive the light along their entire length.—*Beiblätter Ann. der Physik*, 1889, No. 12, p. 882. J. T.

6. *The Cavendish Experiment.*—C. V. Boys has greatly reduced the size of the apparatus used by Cavendish to measure the force of attraction between two masses. Mr. Boys shows that an apparatus the size of an ordinary galvanometer can be employed. As a lecture room experiment the attraction of small masses can readily be shown, even though the resolved force causing motion is no more than the $\frac{1}{200,000}$ of a degree (less than $\frac{1}{10,000,000}$ of the weight of a grain), and this is possible with the comparatively short period of 80 seconds. So perfectly does the instrument work, that there can be no difficulty in making a fairly accurate measure of the attraction between a pair of No. 5 or even of dust shot.—*Nature*, Dec. 19, 1889, p. 154. J. T.

7. *Report on the Magnetic Results of the Voyage of H. M. S. Challenger.*—"The voyage of the Challenger has shown that local magnetic disturbance is found in the solitary islands of the seas, although surrounded by apparently normal conditions similar to those on the great continent. It has been suggested that the magnetic portions of these islands causing the disturbance may possibly have been raised to the earth's surface from the magnetized portion of the earth forming the source of magnetism and tending to prove Airy's conclusion that "the source of magnetism lies deep.

"In view, therefore, of past geological changes and those now in progress, it may fairly be conceived, not only that larger changes have likewise occurred in the distribution of the magnetic portions of the earth appearing here and there on the surface and producing local magnetic disturbance, but that there are others of a more progressive character below the earth's surface which are only made manifest by the secular change observed in the magnetic elements. This conception with regard to secular change is not intended to exclude the view that solar influences may have a small share in producing the observed phenomena."—*Nature*, Dec. 5, 1889, p. 165. J. T.

II. Geology and Mineralogy.

1. *Report of the State Geologist, of New York, for the year* 1888. —Forty-second Annual Report New York State Museum Natural History. Albany, 1889, pp. 351–496. This report and those of the Director of the Museum, the State Entomologist, and the State Botanist, included in the same volume, give evidence that the spirit of scientific investigation that was developed during the geological survey of 1836–'40 is still active and producing results of high scientific value. The report under consideration, by Prof. James Hall, should be in the hands of every working geologist and paleontologist in America.

A short sketch of the contents of Vol. VII, of the Paleontology of New York, is given with a synoptical table of the genera and species of Devonian crustaceans, and a list of the types in the possession of the State Museum. An historical statement of the preparation of Vol. VII. of the same work, on the genera of Brachiopoda, is presented, and followed by a most useful list of 207 genera of the Paleozoic Brachiopoda, prepared by Prof. J. M. Clarke.

A list, prepared by Mr. Charles Schuchert, of the fossils occurring in the Oriskany sandstone of Maryland, New York, and Ontario, exhibits 140 species, 14 of which pass from the Lower Helderberg into the Oriskany sandstone and from the latter, 54 species pass upward into the Upper Helderberg, or Corniferous limestone. Of the 371 species of the Lower Helderberg fauna 3.75 per cent. only pass up into the Oriskany sandstone. A list is given of the specimens originally arranged by Prof. E. Emmons, as representatives of the Taconic System.

Another important list is the record of locality numbers used in labelling the specimens collected for the illustration of the paleontology of the State of New York. A record is given to No. 730 and the list will be continued in the next report.

A note, on the genus Bronteus in the Chemung Rocks of New York, by Prof. J. M. Clarke, describes the discovery of a new species, *B. senescens*, represented by a portion of the pygidium. This is probably the latest recorded appearance of the genus Bronteus (pp. 401–405). Professor Clarke also gives a list of the species constituting the known fauna and flora of the Marcellus epoch of New York.

One of the most interesting papers in the report is that of Professor Clarke on "The Hercynian Question."

The Hercynian Fauna of the Northern Hartz in Germany.— A. Roemer (1843) regarded the fauna as Upper Silurian; subsequently the Cephalopod facies of the fauna was considered as Devonian, and the Brachiopod facies as Silurian. Beyrich (1867) believed the two faunas of Roemer to be one, and suggested their equivalence to Barrande's stages F, G, H, and their relation to the Devonian; Kayser (1878) demonstrated their unity and Devonian character; in 1880 he regarded them as Lower Devonian, repre-

senting a calcareous facies of the Coblenzian and parallel to the F, G, H fauna, but, in 1884, he appears to have resumed his original position in regard to the age of the Hercynian, modifying his conception of the parallelism of the Bohemian fauna by removing from his equivalent the lower portion of F. Novak (1886) shows that the fauna of F was not divisible except into different facies. Frech (1886) made the Bohemian representative of the Devonian series the top of the middle division, and F the equivalent of the Hercynian, as lowest Devonian; in 1887 he placed the base of the Bohemian Devonian at E (Hercynian). Barrois (1889) made the Hercynian, with Beyrich and Kayser (1878, not 1880), a lowest Devonian fauna, but differed from Kayser (1878, 1880) in regarding it, not as a calcareous facies of the Coblenzian, but as such a facies of the older Gedennian, considering the Bohemian stage G as its eqivalent.

Professor Clarke next discusses the equivalent rocks of North America or the Lower Helderberg, Oriskany and Upper Helderberg, and argues that the fauna of the Lower Helderberg is more closely related to that of the Devonian Oriskany fauna than to the Niagara. In conclusion he says: "What has been here written is intended to be only suggested, and the inquiries to which it should give rise are:

"(*a*) Is the normal Lower Helderberg fauna, by virtue of predominant Devonian characters, to be referred to the Devonian system?

"(*b*) Is it the American equivalent of the European Hercynian, i. e. an earliest Devonian calcareous pelagic fauna?

"(*c*) Is it the pelagic fauna, of which the Oriskany Sandstone includes the arenaceous facies?"

This suggestion comes to me with peculiar force at the present time, and, if the Silurian system was to be re-classified to-day, I should favor the following scheme: lower division, Canadian, Calciferous and Chazy; middle division, Trenton and Hudson, and upper division, Niagara and Salina. The summit of the Silurian would be drawn at the Waterlime formation, and the Lower Helderberg would be considered, with the Oriskany sandstone, as lowest Devonian. This, to my mind, is the more natural classification, and divides the Paleozoic into four subequal groups—Cambrian, Silurian, Devonian, and Carboniferous. C. D. W.

2. *Kadaliosaurus priscus* Credner, *a new Reptile from the Lower Permian of Saxony;* by DR. G. BAUR.—Only a few months ago Professor H. Credner described a very important Reptile from the Permian of Saxony, which he called *Palæohatteria longicaudata.** To-day I have received through the kindness of Professor Credner another paper,† which deals with a new reptile from the same locality entirely different from *Palæohatteria.* It is called *Kadaliosaurus priscus.*

When the animal was discovered by the quarrymen it was complete, but in taking it out it was partially destroyed. In this

* Zeitschr. deutsch. geol. Ges., 1888. This Journal, April, 1889.

† Zeitschr. deutsch. geol. Ges., 1889, pp. 319–342, pl. xv.

condition it was found by Mr. F. Etzold, the assistant of Professor Credner. It consists now of parts of the dorsal and caudal vertebræ with ribs, parts of the anterior and posterior extremities, the pelvis, and the complete set of abdominal ossicles. No parts of the skull and the scapular arch were preserved.

Kadaliosaurus had the shape of a Lizard with relatively very long limbs of equal size. There were about twenty dorsal vertebræ each 9–10^{mm} long. The vertebræ are considered biconcave with persistent notochord and short neural spines. The ribs were hollow and one-headed. The sacrum consisted of two vertebræ, with strong sacral ribs; the tail was probably not very long, but possessed very long ribs on the first four vertebræ.*

The constitution of the abdominal skeleton is very remarkable. It extends from the shoulder-girdle to the pelvis, consisting of about 80 strings of ossicles. Each of these strings is composed in the anterior two-thirds of the "plastron" of a median and 5–6 lateral pieces. The distal end of each piece is forked for the reception of each following one. Median pieces are only developed in the anterior part; the lateral pieces diminish in number from front to behind, there being only two or three at the end. According to Credner, from whom this account is taken, these abdominal ossicles were connected by five or six bands of ossicles with the true ribs, but only in the anterior region of the body. The pelvis was very strong and solid. The ilium showed anterior and posterior processes, very much more developed than in *Palæohatteria*, pubis and ischium were plate-like; all three seemed to take part in the acetabulum. The limb-bones were solid, with well-ossified condyles; humerus with an ectepicondylar foramen; femur strongly curved. Fore- and hind-limbs of about the same length. The first row of the tarsus contained two bones, astragalus and calcaneum. The end phalanges formed curved claws.

The question now is, what is the systematic position of *Kadaliosaurus?* Professor Credner calls it a lizard-like reptile, and seems to be inclined to consider it as an ancestral form of the Lacertilia. He lays much stress on the foramen ectepicondyloideum of the humerus. But it seems to me that it is not quite sure yet, whether this foramen is really ect- or entepicondylar. I do not think it possible to determine the exact systematic position of this interesting fossil until the skull and shoulder girdle are known. It may be the ancestor of Lizards, but it may be just as well the ancestor of the archesaurian branch of Reptiles, containing Crocodilia, Dinosauria, Pterosauria, or that of Birds. We have to wait for more material for the solution of this question.

My opinion on the origin of the abdominal ossicles in the Reptilia is entirely supported by the condition found in *Kadalio-*

* These ribs are very peculiar and quite unique among Reptiles, with the exception of the Mesosauridæ, in which the first caudal ribs are also long. In *Kadaliosaurus* the first caudal rib is the longest, the fourth the shortest, the posterior ends of these four ribs are nearly on a straight line.

saurus. A similar arrangement is seen in *Palæohatteria*, *Hyperadapedon* and *Mesosaurus* (Stereosternum). Each of these three genera forms a distinct family of which the *Palæohatteridæ* is the most generalized; the *Hyperadapedontidæ* is a highly specialized family, which probably, or certainly did not leave any descendants; the same I may say of the Mesosauridæ which I consider as aquatic forms of the Proganosauria. The Proterosauridæ and Rhynchosauridæ are in the line of the Rhynchocephalia.

The chronological order of the different families is probably the following:

Palæohatteriidæ:	"Mittel Rothliegendes" (Lower Permian).
Kadaliosauridæ:	"Mittel Rothliegendes" (Lower Permian) a little higher than the Palæohatteriidæ
Proterosauridæ:	"Kupferschiefer" (Upper Permian).
*Mesosauridæ:**	Karoo-system (position not sure, but probably older than Upper Triassic).
Hyperadapedontidæ:	Upper Triassic.
Rhynchosauridæ:	Upper Triassic.

Prof. Huxley has placed *Rhynchosaurus* together with *Hyperadapedon* in one family Rhynchosauridæ; the structure of the abdominal ossicles, so different in both,† leads to a different opinion. I consider *Hyperadepedon* as the representative of a distinct family Hyperadapedontidæ, related to the Proganosauria, forming a highly specialized branch of this primitive order. The Rynchosauridæ are nearly related to the Sphenodontidæ and form a family of the Rhynchocephalia. The Proterosauridæ seem to connect the Rhynchocephalia with the Proganosauria.

3. *American Geological Society.*—The American Geological Society held its first annual meeting on the 26th to the 28th of December, at the American Museum of Natural History, New York. The meeting was a very large one, and comprised geologists from all parts of the country and from Canada, and in this respect, in the value of the many papers presented and the spirit of the discussions, it was a great success. The number of papers presented was nearly forty, and over a sixth of them were by Canadian geologists. The authors included Sir William Dawson, D. P. Penhallow, R. Bell, A. C. Lawson, R. G. McConnell, J. B. Tyrrell, R. W. Ells, P. McKellar, T. C. Chamberlain, James Hall, J. S. Newberry, S. F. Emmons, J. S. Diller, G. H. Williams, I. C. Russell, E. Orton, Wm. B. Clark, Wm. M. Davis, G. F. Wright, W. J. McGee, C. D. Walcott, E. Brainard, H. M. Seely, R. P. Whitfield, C. D. White, A. S. Bickmore, A. Winchell, C.

* *Stereosternum* Cope, from Brazil, which had been considered as of probable Carboniferous age is not distinguishable from *Mesosaurus* from the Karoo-system of South Africa. The South American strata represent the Karoo-system of South Africa.

† The abdominal ossicles of *Rhynchosaurus* are of the same structure as those in *Sphenodon*. In a specimen in the British Museum I have counted thirty-two abdominal bones.

New Haven, Conn., Dec. 10, 1889.

H. Hitchcock, B. K. Emerson, C. R. Van Hise, F. L. Nason, W. Upham, F. J. H. Merrill, W. O. Crosby, P. Fraser, E. D. Cope.

The next meeting is to be held at Indianapolis, at the time of the meeting of the American Association. Prof. Dana was elected President for the coming year. Prof. J. S. Newberry and Alexander Winchell, Vice-Presidents. An address was delivered by the retiring President, Prof. James Hall, on the earlier American geologists.

4. *New fossils from the Lower Cambrian.*—Mr. C. D. Walcott describes, as new, in the Proceedings of the U. S. National Museum, xii, 33–36, *Kutorgina Labradorica* var. *Swantonensis*, Swanton and Highgate Springs, Vt.; *Obolella Atlantica*, Eastern Newfoundland and North Attleborough, Mass.; *Camerella minor*, Stissingville, Dutchess Co., N. Y.; *Coleoloides* (new genus) *typicalis*, a shell near Hyolithes, Manuel's Brook, Newfoundland; *Hyolithes terranovicus* and *H. similis*, same locality as the preceding; *Helenia* (new genus) *bella* same loc.; *Agnostus desideratus*, Salem, Washington Co., N. Y.; *Microdiscus helena*, Manuel's Brook; *Olenellus Bröggeri*, Eastern Newfoundland, and perhaps Shropshire, England; *Avalonia* (new genus) *Manualensis*, a trilobite, Manuel's Brook; *Zacanthoides Eatoni*, Washington Co., N. Y.; *Solenopleura Harveyi*, Manuel's Brook; *S. Howleyi*, same loc.

5. *A Lingula with a cast of its peduncle* has been described by C. D. Walcott in the Proceedings of the U. S. National Museum for 1888 (p. 480). The species is the *L. æqualis* of Hall; its locality, the upper part of the Lorraine shales near Rome, N. Y. Mr. Walcott refers to Davidson's description of a similar case in the *Eichwaldia subtrigonalis* from the Black River limestone in Canada, and of a similar specimen of *Lingula? Lesueuri.*

6. *Cambrian fossils in the Salt Range, India;* by Dr. A. Warth.—Dr. Warth reports the discovery of a *Conocephalites* resembling *C. formosus* Hartt, of the St. John's group, and probably an *Olenus*, in the "Neobolus beds." It indicates a great unconformity in the Salt Range; the beds above the plane of unconformability are Upper Carboniferous and Permian.

7. *Wulfenite from Sing Sing, N. Y.*—Specimens of wulfenite from Sing Sing, N. Y. have recently been received by the editors from Mr. Ernest Schernikow of New York City. It occurs in small red tetragonal crystals of thick tabular habit; the form and blowpipe characters are both characteristic of the species. The crystals are implanted upon a mammillary variety of green pyromorphite, which forms a thin coating upon a friable crystalline limestone. A reddish mammillary mineral very sparingly associated with the pyromorphite has proved to be vanadinite.

8. *Rutile-Edisonite.*—Mügge has recently described some peculiar forms of rutile from the Ural and from Snarum. They show cleavage parallel to the two square prisms and in addition a parting in a direction nearly parallel to faces of the form $\frac{9}{2}$-i (902); the observed angle between two faces (over 100) was 36° 51′ to 37° 47′, while for rutile we have $902 \wedge 90\bar{2} = 38° 4'$. In con-

nection with this the author calls attention to the form of TiO_2 from North Carolina described as a dimorphous form of rutile by Descloizeaux,* and shows that it is apparently beyond doubt to be explained in this way.—*Jahrb. Min.*, i, 231, 1889.

9. *Native Gold in Calcite;* by J. S. DILLER (Communicated).—While at Minersville, Trinity County, Cal., last summer, Mr. Bates of that place showed me several excellent specimens of native gold associated with calcite. They were obtained from a mine on Digger Creek, about a mile above Minersville. I visited the locality in a narrow gulch and found that the mine, although not worked at present, was once vigorously and profitably operated. Two drifts were run into the hillside for nearly 100 feet and considerable gold removed. The calcite occurs in small lenticular masses in a dark carbonaceous shaly rock which is sometimes black and slickensided with a graphitic aspect. The shaly layer is highly inclined and crumpled and varies from one inch to fifteen feet in thickness. The calcite is very irregularly distributed in the dark layer and is not always auriferous, but is occasionally very rich in gold. One of Mr. Bates's specimens is nearly as large as a fist and three-fourths of its volume was estimated to be native gold. Quartz also has been found in the mine but it is less abundant than the calcite and rarely auriferous.

The strata belong to the auriferous slate series and are considerably metamorphosed. In the dark mass containing the calcite as well as beneath it in an impure limestone, there is considerable pyrite which by its decomposition coats portions of the mine with copperas and oxide of iron. It may be that the gold came from the pyrite. Mrs. J. H. Tourtellette of Minersville has presented several specimens to the National Museum of Washington, D. C.

Washington, D. C., Dec. 11, 1889.

10. *Brief Notices of some recently described Minerals.*—WURTZILITE. A kind of bitumen described by W. P. Blake from the Uintah Mts., Wasatch Co., Utah, and named after Dr. Henry Wurtz of New York. It is a firm solid, having a brilliant luster and breaking with a conchoidal fracture; it has a deep black color in reflected light, but translucent and reddish in thin splinters. It is sectile and is more or less elastic in thin shavings, the elasticity increasing when it is slightly warmed. The hardness is between 2 and 3, and the specific gravity 1·030. It becomes soft and plastic in boiling water and in the flame of the candle takes fire and burns with a bright bituminous flame. It resists the usual solvents of bitumen. Wurtzilite is related to elaterite and also resembles in some points the uintahite or gilsonite obtained from the same region.—*Eng. Mining Journal*, Dec. 21, 1889.

FERROSTIBIAN, PLEURASITE, STIBIATIL, EPIGENITE. Minerals described by Igelström as occurring at the Sjö mines, Grythytte

* Bull. Soc. Min., ix, 184, 1886; this has later been made a new species by Hidden under the name *Edisonite*, this Journal, xxxvi, 272, 1888.

parish, Sweden. *Ferrostibian* is found imbedded in rhodonite in well developed monoclinic crystals. The color is black to blackish-gray, the streak brown, the luster submetallic, the hardness 4; it is weakly magnetic. An analysis gave

Sb_2O_3	FeO	MnO	H_2O	
14·80	22·60	46·97	10·34	Mg_2CO_3, $CaCO_3$ 2.14, insol. 2·24=99·09

Pleurasite from the same locality is regarded as an arseniate of iron and manganese containing chlorine. It has a blue-black color, submetallic luster, a conchoidal fracture, and hardness of 4. No analysis is given, the assumed composition being based upon some blow-pipe and other qualitative tests. *Stibiatil* is another imperfectly studied mineral, regarded as a hydrous antimoniate of manganese and iron, associated with polyarsenite (sarkinite). It occurs in crystals, referred to the monoclinic system, and is black and opaque with metallic luster and has a hardness of 4.

EPIGENITE.—A hydrous silicate of manganese and magnesium occurring in brownish red bladed masses imbedded in tephroite. An analysis gave

SiO_2	MnO	MgO	FeO	H_2O
29·50	40·60	20·05	*tr.*	9·85=100·

The formula deduced is $R_2SiO_4+H_2O$ which places it near the hydrotephroite of the same author. The same name has been used before for a mineral related to enargite.—*Geol. Förening i Stockholm Förhandl.*, xi, 389, 1889.

11. *Native Arsenic from Colorado.*—Mr. CLARENCE HERSEY has announced the discovery of native arsenic in a mine yielding silver and some gold, five or six miles west of Leadville, Colorado. The mineral occurs in nodular concretionary forms so brittle that they readily break to fragments.

12. *Catalogue of Minerals found in New Jersey*, by F. A. CANFIELD, 23 pp. Trenton, N. J. 1888.—From the final report of the State Geologist, vol. ii. This well prepared list will be useful to all interested in the local mineralogy of New Jersey.

III. BOTANY AND ZOOLOGY.

1. *Hybrids.*—G. DE SAPORTA (Comptes rendus, Oct. 28, 1889) gives an interesting account of certain hybrids observed in Provence. These are (1) *Pinus halepensis-pinaster*, the mother-plant being assumed to be *P. pinaster*, and the father, *P. halepensis*. The hybrid has the port of the mother but with less regularity of branching, and having the grayish bark scaling off in large flakes. The leaves, so far as their size is concerned, are just between the two. (2.) *Quercus pubescente-Mirbeckii.* The hybrid is exactly intermediate between the two parents. The mother, *Q. Mirbeckii*, is from Africa. (3.) *Tilia platyphyllo-argentea* has hybrids of all ages, showing that the fertilization is not, by any means, confined to any particular year.

It is noteworthy that of the species mentioned above, two are monœcious, and one hermaphrodite. G. L. G.

2. *The cause of the ascent of sap.*—JOSEF BOEHM (Berichte der Deutsch. bot. Gesellschaft, Nov. 28, 1889) states the results of certain interesting experiments which he interprets as proving that in plants which are "transpiring," the absorption of water by the roots is caused by capillarity, while the transfer of water to the parenchyma of the leaf is brought about by the pressure of air within the tissues. The experiments appear to the present reviewer to be capable of an entirely different explanation, and a detailed account of some modifications of Boehm's line of work will be shortly published, but it will be well to give briefly at this time an outline of the suggestive method pursued by Boehm. To show that the absorption of liquids by roots is not due to osmosis (since that depends on the activity of the protoplasmic lining of the cells of the root-hairs and adjacent epidermis) he *boils* the roots in water in order to kill the living matter. He finds that after this destructive process, absorption of liquids goes on as before; at any rate, the supply of liquid to the leaves is sufficient to prevent any wilting. To this subject it is proposed to recur at an early day. G. L. G.

3. *Memoirs of the Torrey Botanical Club.*—Vol. I, No. 1, Studies of the Types of various species of the genus *Carex*. By L. H. BAILEY. pp. 85. No. 2, Marine Algæ of the New Jersey Coast and adjacent waters of Staten Island. By ISAAC C. MARTINDALE. pp. 22. These are in octavo, and are unexceptionable in their typographical execution. From the titles of these first two memoirs it is plain that the Club has determined to appeal at the very outset to a wide range of specialists, and we trust earnestly that this praiseworthy effort will meet with the heartiest response. The Bulletin of the Torrey Club is known to all of our botanical readers, and we hope that this their supplementary publication will soon receive the substantial aid of all our botanists.

It is certainly creditable to botanical science in this country that our two botanical journals, the Bulletin of the Torrey Club, and the Botanical Gazette, should be so well patronized. Both of them are excellent, and deserve, and should receive strong support at the hands of all amateur and professional botanists in this country. G. L. G.

4. *On the nitrification of Ammonia.* — TH. SCHLŒSING (Comptes rendus, Dec. 9, 1889) has continued his experiments on the behavior in the soil of certain salts of ammonia, and now reaches the conclusion that the process of nitrification is not only accompanied by the formation of nitrites, as has long been known, but that these products distinctly retard the further progress of nitrification. The nitrifying microbes are plainly hindered in their work by these partially oxidized substances. G. L. G.

5. *On the part which Ammonia plays in the nutrition of the higher plants.*—A. MÜNTZ (Comptes rendus, 21 Oct., 1889) first traces the history of the subject, pointing out the successive phases of development of the subject, going as far back as the time in which it was held that only organic compounds of nitro-

gen could be made available to plants, down to the present. His observations are directed chiefly to the demonstration of the thesis that ammonia can be utilized by vegetation without previous nitrification. For this purpose he made use of soil thoroughly sterilized and freed from every trace of nitric or nitrous acids in any combination, and in these soils provided with ammonia, he carried on his cultures. His experiments are not sufficiently extensive to settle the question, but they go very far to show that the nitrification of ammoniacal manures cannot be regarded as indispensably necessary to the utilization of the nitrogen therein contained. G. L. G.

6. *Fixation of Nitrogen by Leguminous plants*, (Comptes rendus, 28 Oct., 1889).—E. Bréal has already communicated to the French Academy the results of his experiments showing that it is possible to inoculate the roots of Leguminous plants from the tubercles of other species, therefrom transferring bacteria which produce tubercles. The same experimenter gives now the chief facts in regard to his cultivation of plants of this order for the purpose of ascertaining the relations of the tubercles to the utilization of the nitrogen of the soil. His experiments can be fairly interpreted as confirmatory of some of the studies of Hellriegel, Wilfarth and Berthelot. G. L. G.

7. *Economic Mollusca of New Brunswick*, by W. F. Ganong.—Bulletin viii, of the Natural History Society of New Brunswick, Saint John, N. B., 1889, contains facts on the distribution of mollusks of the coast which are of much interest in Quaternary geology.

9. *Bibliotheca Zoologica*, II, Verzeichniss der Schriften ueber Zoologie welche in den periodischen werken enthalten und vom Jahn 1861–1880, Selbständig erschienen sind, bearbeitet von Dr. O. Taschenberg (Wm. Engelmann, Leipzig).—The seventh part of this important work (see vols. xxxiii *et seq.*) has recently been issued including signatures 241–280, pp. 1971–2290.

IV. Miscellaneous Scientific Intelligence.

1. *American Metrological Society.*—This society, founded in 1873, has elected the following officers for the year 1890:

President, B. A. Gould, Cambridge, Mass.

Vice-Presidents, T. R. Pynchon, Hartford, Conn.; Sanford Fleming, Ottawa, Canada; T. C. Mendenhall, Washington, D. C.; T. Egleston, New York City; R. B. Fairbairn, Annandale, N. Y.; J. H. Van Amringe, New York City. Treasurer, John K. Rees, New York City. Recording Secretary, John K. Rees, New York City. Corresponding Secretary, O. H. Tittmann, Washington, D. C.

Members of the Council, H. A. Newton, Cleveland Abbe, R. H. Thurston, A. M. Mayer, C. F. Brackett, W. F. Allen, Simon Newcomb, S. P. Langley, E. O. Leech, Geo. Eastburn.

The following is cited from the Constitution of the Society:

Objects of the Society.—(1) To improve existing systems of

weights, measures and moneys, and to bring them into relations of simple commensurability with each other.

(2.) To secure universal adoption of common units of measure for quantities in physical observation or investigation, for which ordinary systems of metrology do not provide; such as divisions of barometer, thermometer, and densimeter; amount of work done by machines; amount of mechanical energy, active or potential, of bodies, as dependent on their motion or position; quantities of heat present in bodies of given temperatures, or generated by combustion or otherwise; quantity and intensity of electro-dynamic currents; aggregate and efficient power of prime movers; accelerative force of gravity; pressure of steam and atmosphere; and other matters analogous to these.

(3.) To secure uniform usage as to standard *points of reference*, or physical conditions to which observations must be reduced for purposes of comparison; especially temperature and pressure to which are referred specific gravities of bodies, and the zero of longitude on the earth.

(4.) To secure the use of the decimal system for denominations of weight, measure, and money derived from unit-basis, not necessarily excluding for practical purposes binary or other convenient divisions, but maintained along with such other methods, on account of facilities for calculation, reductions, and comparison of values, afforded by a system conforming to our numerical notation.

Modes of operation.—(1) The society will endeavor to carry out its objects, by appeals to congress, state legislatures, boards of education, higher institutions of learning, and to directors and teachers of schools of every grade throughout the country, urging adoption of measures in their several spheres for diffusing information as to the present state of the world's metrology and recent progress in its reform, and specially for instructing the rising generation in these matters, to the end that our people may be early and fully prepared to act intelligently on the important questions connected with weights and measures.

(2.) By invoking the aid and coöperation of bodies organized to consider questions of scientific or social interest, boards of trade, chambers of commerce, societies of engineers, industrial associations, professions and trades, in this country and elsewhere.

(3.) By specially urging scientific bodies to open communications with similar bodies in other countries, with a view to general agreement on values to be henceforth uniformly given to units of measure and points of reference which particularly concern them: i. e., to the so-called constants of science.

(4.) By memorializing Congress in favor of laws requiring the use, in certain departments of the public service, of metric weights and measures, wherever such legislation may tend to relieve commerce of some of its burdens, to facilitate international communication, to promote international jurisprudence, and to familiarize our own people with the benefits of that system of metrology, with the least interference with their ordinary habits of thought or daily business.

(5.) By direct appeals to the people through the public press, and by circulating so far as means allow, books and documents informing the public of the defects of the common system of weights and measures, the means most proper for its amendment, and the great advantages which the acceptance of a universal system would insure to all mankind.

2. *Royal Society of N. S. Wales*, vol. xxii, Part 2. 1888.—This number of the Journal and Proceedings contains an important illustrated paper by J. E. Tennison Woods on the anatomy and life-history of Mollusca peculiar to Australia; a paper on the desert-sandstone of Australia, making it largely of volcanic origin, by the same; a catalogue with comparative observations of the older Tertiary fossils of Australia, by Prof. R. Tate; notes on N. S. W. minerals, by A. Liversidge; and other papers.

3. *Reports of Examinations of Waters and Water Supply and related subjects during the years* 1886–89, by E. W. HILGARD.—The following note on *the change of saline condition attending concentration* in some California lakes is taken from this valuable report.

The three lakes of the Upper San Joaquin Valley—Kern, Buena Vista and Tulare—were once connected, and the alkali contained in their waters is manifestly of the same origin. Evaporation has for years past gradually concentrated their waters, for want of the natural influx (Kern River) now diverted by irrigation ditches. But analysis showed that apart from concentration, a change in the *ratio* between the soluble salts has been going on as evaporation progressed. The cause of this change was not obvious.

The table below giving the results of the analyses made in 1880 and one lately made of the water of Tulare Lake, which has likewise been seriously diminished by evaporation so as to more than double its solid contents, shows a difference has occurred corresponding to that which in 1880 existed between Kern and Tulare Lakes. That is, the relative proportions between sodic carbonate on one hand and common and Glauber's salts on the other, have changed, and are tending toward the same ratio that then existed in Kern Lake, evidently as the result of concentration. There has been a relative diminution of the sodic carbonate; in conformity with the rule shown in our experiments, above reported, that as the amount of neutral alkali salts is increased, a relatively smaller amount of carbonate is formed under the influence of $CaCO_3$ and CO_2. The calcic carbonate required for the reaction is abundantly present both in the waters and in the deposits of the lake. The following table shows the *increase of alkali carbonates by concentration.*

Locality.	Total Residue.	Carbonate of Soda.	Common and Glauber's Salt.
1880, Tulare Lake, near mouth of Kings River,	38·55	1	1·11
1880, Tulare Lake, middle	81·83	1	1·29
1880, Tulare Lake, south end	81·49	1	1·35
1888, Tulare Lake, middle	204 00	1	1·58
1889, Tulare Lake, north end	303·07	1	1·94
1880, Kern Lake	211·50	1	1·78

Doubtless a host of similar examples can be found within arid regions. We hope before long to communicate additional results.

4. *Arthrolycosa antiqua of Harger*, volume vii, 219, 1874, and xxxviii, 219, 1889.—Justice to Mr. Harger requires it to be stated —what he did not state in his paper—that he was not at liberty to develop any covered parts of the spider on the specimen put in his hands for description. The specimen was regarded as a very valuable one, and the parts of the animal were supposed to be fully exposed. J. D. DANA.

Transactions of the Kansas Academy of Science, vol. x, 1885–86. 154 pp. 8vo.—"A fossil bird-track" from the Dakota sandstone is described by Professor F. H. Snow, on pages 3 to 6, with an accompanying figure; a historical sketch is given of geological work in the State, by Robert Hay and A. H. Thompson, on pages 45 to 52; and besides there are other short papers of value.

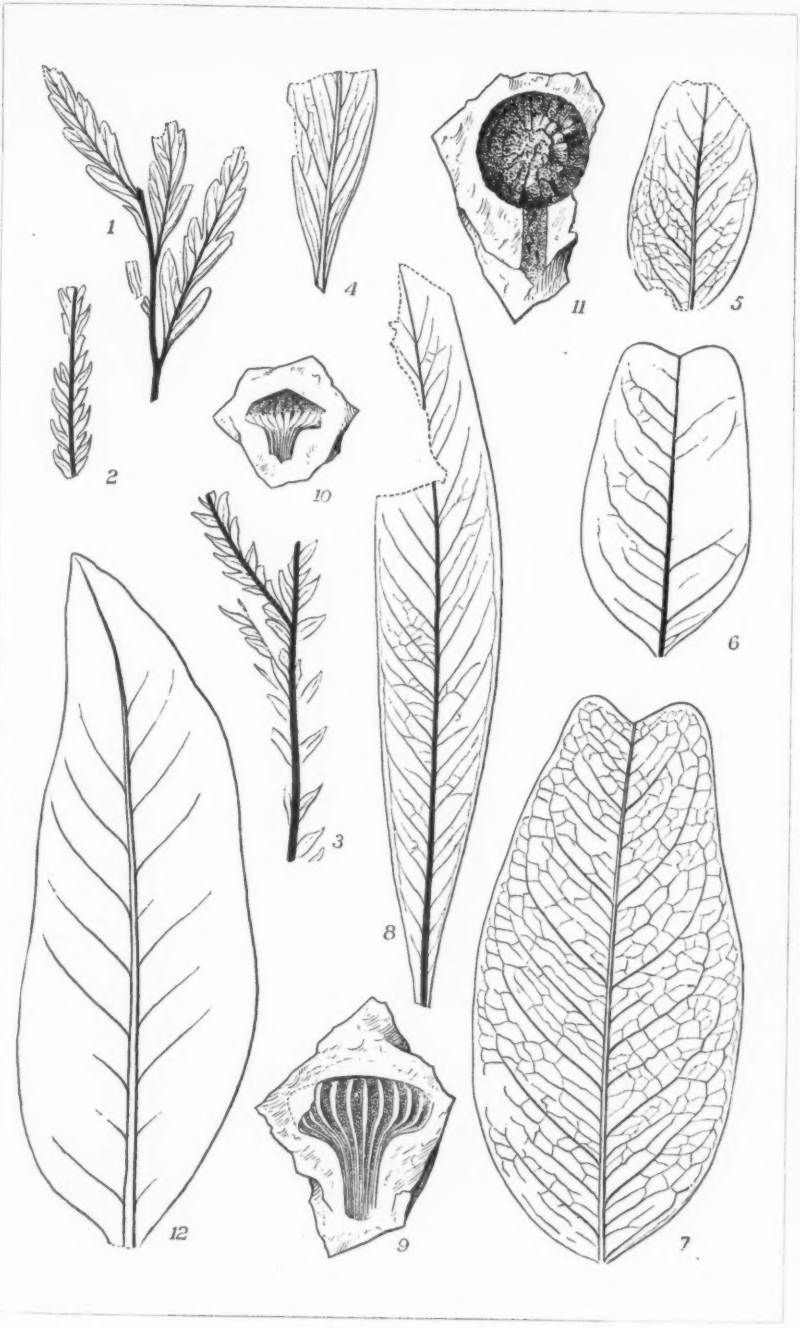
A theoretical and practical treatise on the strength of beams and columns, by ROBERT H. COUSINS. 170 pp. 8vo. New York, 1889 (E. & F. N. Spon).

Richtigstellung der in bisheriger Fassung unrichtigen mechanischen Wärmetheorie und Grundzüge einer allgemeinen Theorie der Aetherbewegungen von A. R. von Miller-Hauenfels. 256 pp. 8vo. Vienna, 1889.

Der Einfluss einer Schneedecke auf Boden, Klima und Wetter; von A. Woeikof, Prof. Phys. Geogr. Univ. St. Petersburg. Penck's Geograph. Abhandl. Wien, iii, heft 3. 116 pp. 1889.

OBITUARY.

CHARLES ALBERT ASHBURNER.—The able geologist, of Pennsylvania, Mr. Charles A. Ashburner, died at Pittsburg, on the 24th of December in his 36th year, having been born in Philadelphia in February, 1854. He left the University of Pennsylvania with high honors in 1874, and during the past year received from the University the honorary degree of Doctor of Philosophy. Soon after graduation, on the organization of the Second Geological Survey of the State, he became an assistant in the survey, and in this position the larger part of his geological investigations were carried on. Mifflin, Juniata, McKean, Elk, Forest and Cameron counties were surveyed and reported on by him, and also with great completeness and excellence of maps and sections, the anthracite coal fields which were made his special work in 1880. In 1885, when the director of the survey, Prof. Lesley, commenced the preparation of his final report on the survey, Mr. Ashburner was put in charge of the executive business of the whole State Survey. In 1887 Mr. Ashburner was given the Bituminous Coal-Region for investigation and report. Subsequently he became connected with the Philadelphia Natural Gas Company, as an expert, and made Pittsburg his place of residence. Mr. Ashburner was a man of great energy and executive ability, and of thoroughness in all his work, as his various reports show. The Pennsylvania Survey owes much of the value of its results to his labors.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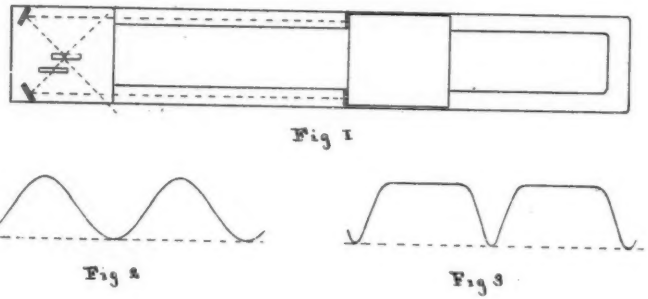

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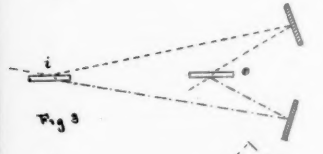

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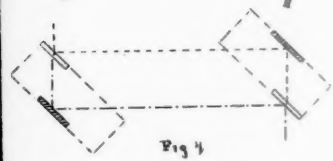

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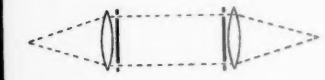

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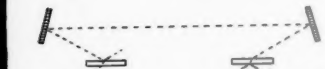

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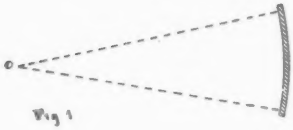

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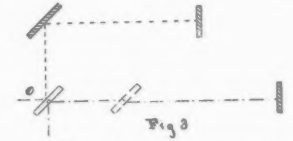

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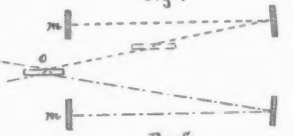

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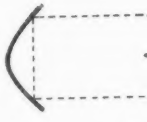

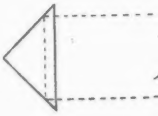

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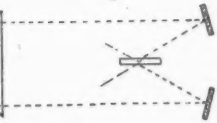

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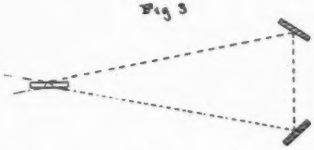

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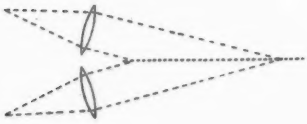

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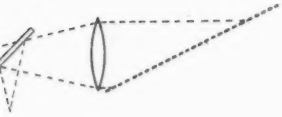

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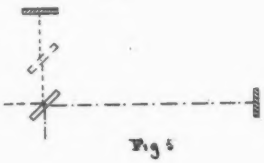

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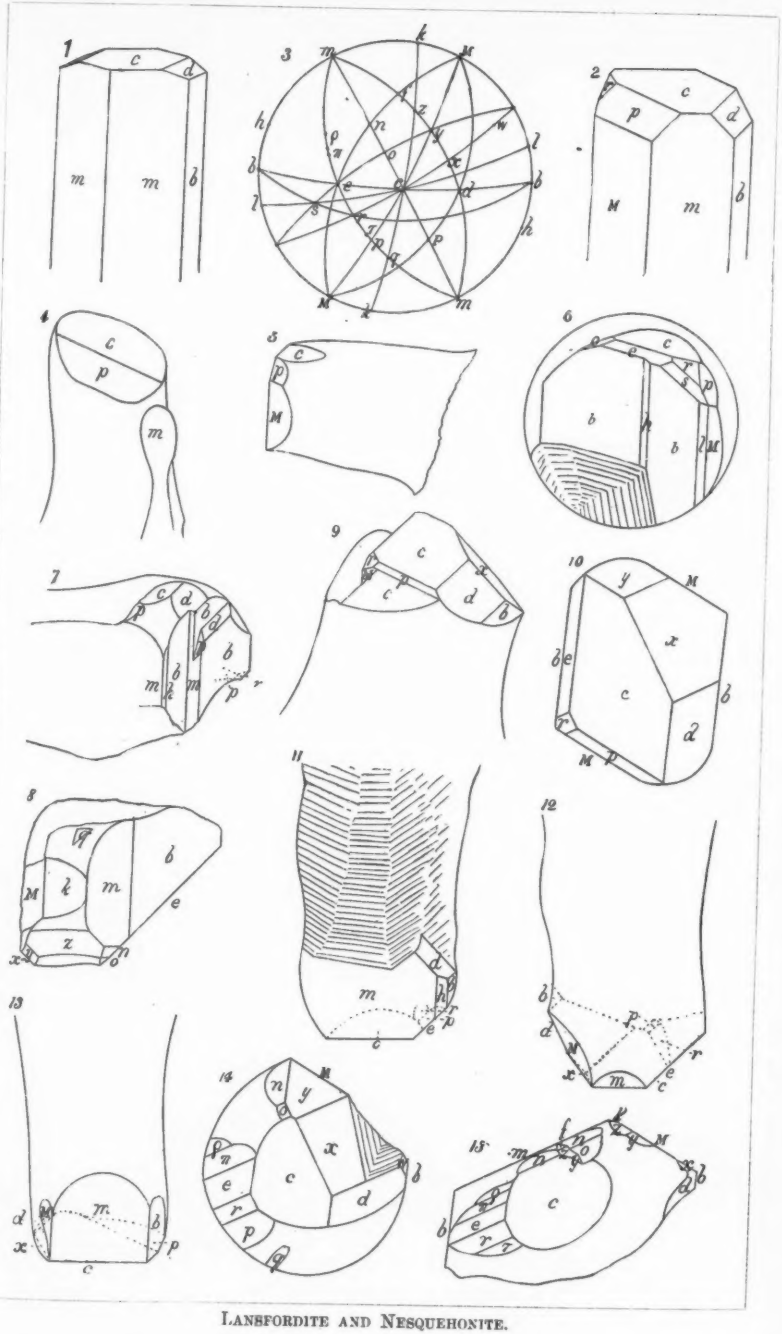

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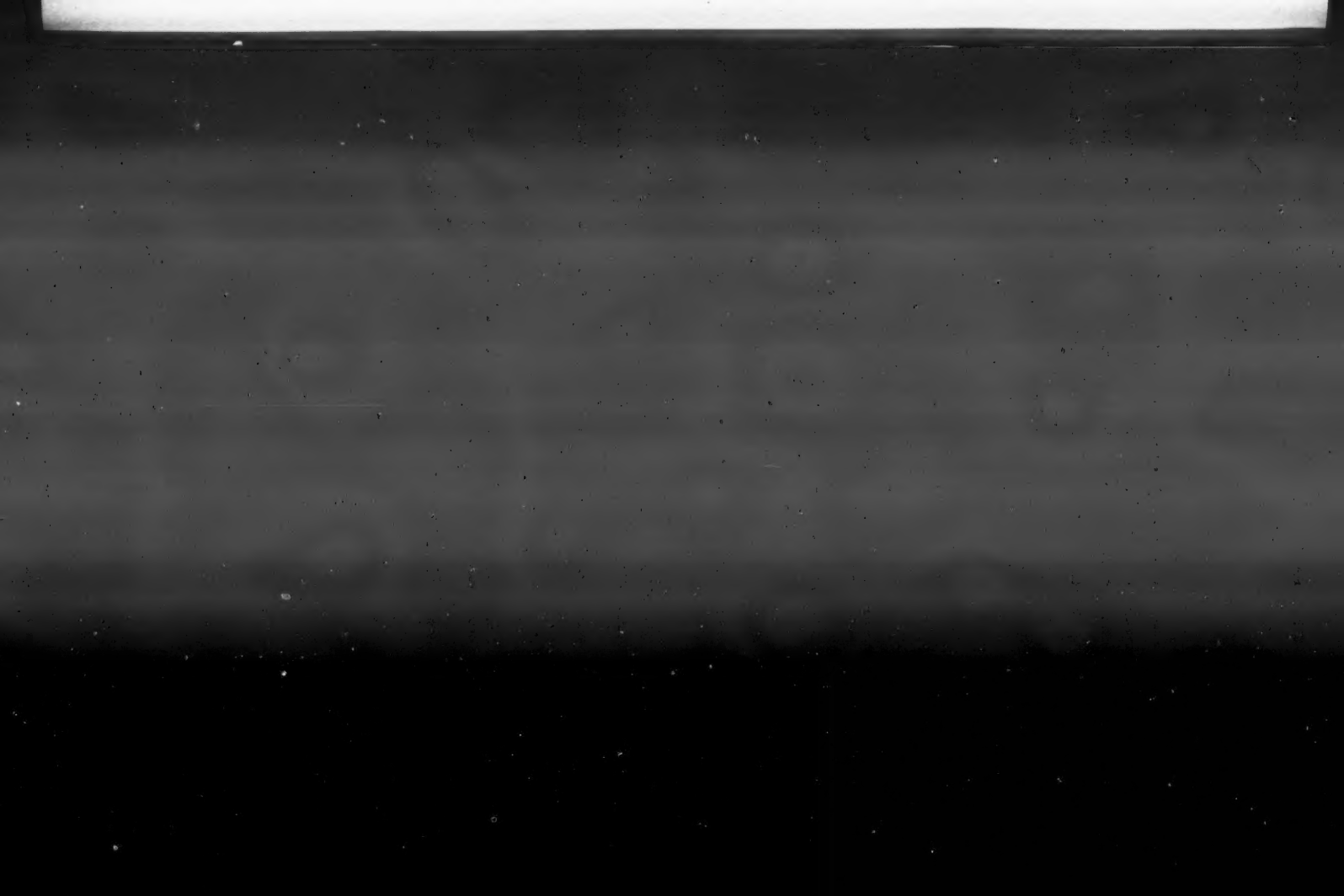

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